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AUREOMYCIN FOR GROWING AND FATTENING BEEF ANIMALS[1]

T. W. Perry, W. M. Beeson, E. C. Hornback and M. T. Mohler

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INCREASED growth rate and decreased incidence of scours in dairy calves due to antibiotic feeding has been reported by several investigators. (Bartley *et al.*, 1950; Jacobson *et al.*, 1951; Loosli, 1951; Loosli *et al.*, 1951; Loosli and Wallerman, 1951; Rusoff, 1951; Rusoff and Davis, 1951; and Voelker and Cason, 1951). In general, these calves, in which antibiotic feeding produced growth stimulation, were from 1 day to 150 days of age, or at an age when rumen development was far from complete.

Bell *et al.* (1951) reported a deleterious effect and Neumann *et al.* (1951) reported no beneficial effect from the feeding of antibiotics to yearling beef animals in which rumen development had progressed much further.

The object of this research was to investigate further the effect of feeding aureomycin to growing and fattening beef animals in both suckling calves in which there was little or no rumen development and in older animals in which rumen development had progressed further.

Experimental

Trial I. February 15–October 11, 1951

Thirteen calves from the experimental Shorthorn herd were assigned to one of two treatments at time of birth. Twenty-four mg. aureomycin per one hundred pounds liveweight was administered by capsule daily to six of the calves whereas the other seven received no aureomycin and served as the control. The calves ran with their dams in dry lot until such time as pasture was available. A creep ration consisting of corn 66.7%, oats 20.0%, and soybean oil meal 13.3%, was available both in drylot and on pasture. Data were collected on each calf until it reached eighty days of age.

Trial II. March 8–September 6, 1951

Ten yearling Shorthorn steers and heifers averaging 540 pounds were divided uniformly into two lots and fed a ration which was calculated

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 743, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

to support normal growth and which consisted of alfalfa hay and simple minerals free choice, corn 4.8 lb., oats 1.2 lb., and soybean oil meal 1.0 lb. per animal daily, for twenty-six weeks. One lot served as the control and received the ration listed. The second lot received the above ration plus 63.5 mg. aureomycin per animal daily for the first fourteen weeks; 127 mg. per animal daily for the next six weeks; and 190.5 mg. per animal daily for the last six weeks. The antibiotic was incorporated in the supplement.

Trial III. January 27–August 14, 1953

Yearling Hereford steers averaging 713 pounds were divided into four drylots of nine steers per lot. Two lots were fed a growing type ration, and the other two were fed a fattening ration. The two lots being fed a growing ration were fed a basal ration of Purdue Cattle Supplement A, 3.5 lb. (Beeson and Perry, 1953), simple minerals, free choice, and a controlled intake of ground corn cobs such that the appetite of the lot consuming the smaller amount controlled the amount fed the other lot. One lot served as the control and received only the basal ration. The second lot received 75 mg. aureomycin per steer daily in their supplement.

The two lots fed the fatteining ration were fed a basal ration of Purdue Cattle Supplement A, 3.0 lb.; simple minerals, free choice; and a full-feed of a fattening combination of ground shelled corn and ground corn cobs on a controlled intake basis as described above. One lot served as the control and received only the basal ration. The second lot received 75 mg. aureomycin per steer daily in their supplement in addition to the basal ration.

Trial IV. May 27–July 22, 1953

Twenty-five Shorthorn steers and heifers were divided into five lots on the basis of sex and age and were fed a basal ration consisting of Purdue Cattle Supplement A, 3.50 lb., ground corn cobs, free choice and simple minerals, free choice, in drylot. Lots I and III served as the control and received the basal ration listed. Lots II and IV received the basal ration plus 75 mg. aureomycin per animal daily in their supplement. Lot V received the basal ration plus increasing levels of aureomycin in the supplement as follows: 25 mg. per steer daily for the first seven days; 50 mg. per day for the second seven days; and then a constant level of 75 mg. per steer daily starting with the third week.

Results and Discussion

Trial I. Suckling Calves

Scouring seldom occurred in the lot receiving 24 mg. aureomycin per 100 lb. liveweight whereas scouring was a definite problem in the control lot which received no aureomycin. Scouring in the control lot became so severe that therapy had to be undertaken. Aureomycin completely cured all scouring, when administered, to the calves in the control lot. The amount required varied tremendously (from 12 mg. total to 231 mg. total) over a period of from one to three days. These

TABLE 1. THE EFFECT OF AUREOMYCIN ON SUCKLING CALVES FROM BIRTH TO EIGHTY DAYS OF AGE
(Trial I)

Item	February 15–October 11, 1951 Control	Treated
Number of calves	7	6
Number of death losses	0	0
Av. initial weight, lb.	60.9	60.0
Av. weight at 80 days, lb.	188.2	202.7
Av. total gain, lb.	127.3	142.7
Av. daily gain, lb.	1.59	1.78
Incidence of scouring, days	38.0	7.0
Aureomycin per 100 lb. body wt., daily	....	24 mg.

findings are in agreement with those of Bartley *et al.* (1950), Loosli *et al.* (1951), Murley *et al.* (1951) and Rusoff and Davis (1951) who reported decreased scouring in young dairy calves by the feeding of aureomycin.

Although the difference was not statistically significant, aureomycin fed calves averaged 14.5 pounds per calf more at eighty days of age than control calves not fed aureomycin (table 1). Comparable growth stimulation was noted in dairy calves by the investigators referred to above.

Trial II. Yearling Fed A Growing Ration

During the first week of the trial there was difficulty in keeping treated yearlings on feed. Newmann *et al.* (1951) and Bell *et al.* (1950) reported anorexia also in yearling beef heifers and steers fed aureomycin.

Treated calves gained at an average rate of 1.64 lb. per day and

control animals gained 1.52 lb. per day over the twenty-six week period. Control animals required nine percent more feed per unit gain than control animals (table 2).

TABLE 2. AUREOMYCIN FOR YEARLING HEIFERS AND STEERS
(Trial II)

Item	March 8–September 6, 1951 Control	Treated [1]
Number of animals	5	5
Av. initial wt., lb.	550	531
Av. final wt., lb.	826	821
Av. total gain, lb.	276	310
Weeks on trial	26	26
Av. daily gain, lb.	1.52	1.64
Av. daily feed		
Hay, lb.	12.9	12.6
Corn, lb.	4.8	4.8
Oats, lb.	1.2	1.2
Soybean meal, lb.	1.0	1.0
Feed per lb. gain		
Hay, lb.	8.5	7.7
Corn, lb.	3.2	2.9
Oats, lb.	0.8	0.7
Soybean meal, lb.	0.7	0.6

[1] Treatment was as follows: First 14 weeks, 9.07 mg. aureomycin per lb. concentrates; next 6 weeks, 18.14 mg.; last 6 weeks, 27.22 mg.

Trial III. Controlled Intake—Yearling Steers

Since the feeding of aureomycin caused increased feed efficiency in Trial II, it was reasoned that if this effect were actual, the controlling of the intake so that treated and untreated animals consumed the same amount per day would cause the more efficient lot to gain more rapidly. In the case of the two lots being fed the predominantly roughage rations (Lot I and II) the steers receiving 75 mg. aureomycin daily grew significantly faster ($P<0.05$) than the steers receiving no aureomycin. In fact, the treated steers gained 43 pounds more per steer, in the first 84 days, than the control animals. This advantage was maintained but was not increased as the trial progressed. Since the feed intake was equalized between the two lots it would mean the aureomycin fed steers were more efficient (18%) than control animals (table 3).

Aureomycin did not affect the growth and fattening rate of steers on a fattening ration (table 3).

Both lots receiving aureomycin (Lots II and IV) showed a depressed appetite during the first week but rapidly regained normal appetites.

Trial IV. Free Choice Rations to Calves and Yearlings

A mixed group of calves and yearlings showed a response to a daily intake of 75 mg. aureomycin similar to that reported in Trial III.

TABLE 3. AUREOMYCIN FOR YEARLING STEERS ON CONTROLLED FEED INTAKE
(Trial III)

Lot No.	Ration	Daily Feed, Lb.	Feed per Lb. Gain, Lb.	Initial Weight, Lb.	Final Weight, Lb.	Gain per Steer, Lb.	Daily Gain, Lb.
	January 27–July 7, 1953 (161 Days; 9 Steers per Lot)						
I	Gr. corn cobs	15.27	12.2	713	916	203	1.26
	Purdue Suppl. A.	3.50	2.8	...	...	...	....
II	Gr. corn cobs	15.35	10.0	...	...	...	....
	Suppl. A with [2] 75 mg. aureomycin	3.50	2.3	713	960	247 [1]	1.53
	January 27–July 14, 1953 (168 Days; 9 Steers per Lot)						
III	Gr. corn cobs	11.77	5.4	...	...	...	....
	Purdue Suppl. A	3.0	1.4	711	1078	367	2.18
	Gr. shelled corn	9.55	4.4	...	...	...	....
IV	Gr. corn cobs	11.77	5.4	...	...	...	....
	Suppl. A with [2] 75 mg. aureomycin	3.0	1.4	715	1078	363	2.16
	Gr. shelled corn	9.54	4.4	...	...	...	....

[1] L.S.M.D. for gain per steer 5% level, 38.0 lb.
[2] 75 mg. aureomycin per animal daily.

Aureomycin fed animals (Lots II and IV, table 4) gained an average of 27 pounds more per animal (statistically significant, $P<0.01$) than control animals over a 56-day drylot trial.

Addition of aureomycin gradually (Lot V) did not give the growth stimulation observed when a level of 75 mg. per steer daily was started (Lots II and IV). Aureomycin fed animals were 20 percent more efficient in feed utilization than control animals receiving no aureomycin.

Summary

The administration of aureomycin to suckling calves at a level of 24 mg. per 100 liveweight decreased scouring and gave an apparent growth stimulation.

Yearling steers receiving 75 mg. aureomycin per animal daily gained 43 pounds more ($P<0.05$) than control animals on a ground corn cobs-Supplement A type of ration when the appetite of the lot consuming the least amount of ground corn cobs controlled the amount the other lot received. Aureomycin fed steers required 18% less feed per unit gain.

Aureomycin feeding had no effect on growth rate or feed efficiency of fattening steers on a controlled intake basis described above.

TABLE 4. AUREOMYCIN FOR CALVES AND YEARLINGS ON ROUGHAGE RATION

(Trial IV)

Lot No.	Ration	Daily Feed, Lb.	Feed per Lb. Gain, Lb.	Initial Weight, Lb.	Final Weight, Lb.	Gain per Animal, Lb.	Daily Gain, Lb.
	May 27–July 22, 1953 (56 Days; 5 Animals per Lot)						
I and III	Gr. corn cobs	15.22	9.0	682	777	95	1.69
	Purdue Suppl. A	3.50	2.1	...	...	...	....
II and IV	Gr. corn cobs	15.58	7.2	680	802	122 [3]	2.18
	Suppl. A with [1] 75 mg. aureomycin	3.50	1.6	...	...	...	....
V	Gr. corn cobs	14.81	8.1	678	781	103	1.83
	Suppl. A with [2] graded aureomycin	3.50	1.9	...	...	...	....

[1] 75 mg. aureomycin per steer daily.
[2] During the first week, the animals in Lot V received 25 mg. aureomycin per steer daily; during the second week, 50 mg. daily; and starting with the third week, 75 mg. daily.
[3] L.S.M.D. for gain per steer, 1% level, 19.4 lb.

Calves and yearlings receiving 75 mg. aureomycin gained 27 pounds more (statistically significant, $P<0.01$) and required 20 percent less feed per unit of gain than control animals on a basal ration of ground corn cobs, and simple minerals, free choice, and Purdue Cattle Supplement A, 3.5 lb. per day.

In all cases, the introduction of aureomycin to the ration caused a temporary depression in appetite for two to four days during the first week.

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EFFECT OF TERRAMYCIN FED TO HOLSTEIN CALVES ON GROWTH, IN-VITRO CELLULOSE DIGESTION AND B-VITAMIN SYNTHESIS [1, 2]

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NUMEROUS experiments have demonstrated that the growth rate of young calves can be increased over that obtained on a good natural diet by the inclusion of low levels of certain antibiotics in the diet. One of these, terramycin, usually has produced a favorable growth stimulus (Voelker and Cason, 1951; MacKay, *et al.*, 1953; Voelker and Jacobson, 1953); but Murdock, *et al.* (1951) and Cason and Voelker (1951) reported only small differences in growth of supplemented calves as compared to controls. MacKay and coworkers (1953) fed the antibiotic to older calves and noted an increase in the growth rate for the first weeks of feeding followed by a gradual decline to the same rate as controls. Supplemented calves were slightly heavier than controls at the end of the experimental period, but not significantly so.

The trials herein reported consisted of a study of the effect of terramycin supplementation in the diet of male Holstein calves on growth; and on the development of certain rumen functions as measured by the cellulose digestive power of the rumen fluid, and the levels of thiamine and riboflavin in the rumen fluid. It was hoped that such studies would help to explain the mode of action of the antibiotic.

Experimental

Trial I

Healthy male Holstein calves, 1 to 4 days of age and weighing between 90 and 110 pounds were divided into equal groups as they were brought to the experimental barn. Six controls were fed a milk replacement diet developed by Williams and Knodt (1949), and 6 experimental calves received this same replacement to which had been added 2 gm. of crystalline terramycin hydrochloride per 100 lb. of replacement. At this level, calves received approximately 20 mg. of terramycin per 100 lb. body weight per day. During the 7th week each

[1] Authorized for publication as paper No. 1813 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

[2] The terramycin used in these trials was kindly supplied by Chas. Pfizer and Co. Inc., Brooklyn, N. Y.

of the groups was divided into subgroups of 3 calves each. Three of those previously receiving terramycin no longer received it, while the other 3 were fed crystalline terramycin in a sucrose carrier *via* gelatin capsule. They were fed increasing amounts of the antibiotic to correspond to 20 mg. per 100 lb. body weight per day, based on the mean body weight of the group. The control replacement calves also were divided, 3 continuing as controls and the other 3 receiving terramycin by capsule. Three additional calves served as milk-fed controls. They received 400 lb. of Hostein herd milk over a period of 40 days from the time they entered the experiment.

Other details of care and feeding were uniform for all calves. They were fed a calf starter *ad libitum* up to a daily maximum of 5 lb. per calf and all received a mixed grass-legume hay *ad libitum*. Records of starter and hay consumption were kept.

Records were made of the body weight and height at withers of each calf initially and at weekly intervals throughout the 16-week experimental period. At the ages of 6, 12 and 16 wks. rumen samples were obtained from each calf by the use of a stomach tube. Samples were strained through 4 thicknesses of cheesecloth into a flask which was stoppered, kept from light and at body temperature and taken to the laboratory as quickly as possible. A subsample was withheld for the purpose of making chemical determinations for thiamine (Assoc. of Vitamin Chemists, 1947) and for riboflavin (Loy, 1947). Only sufficient rumen fluid for B-vitamin analysis could be obtained from the animals at age 6 weeks; however, at ages 12 and 16 weeks there was enough for introduction into an artificial rumen for the purpose of determining the cellulose digestive power of the microorganisms contained in the rumen fluid. The artificial rumen set-up was modeled after that of Burroughs *et al.* (1950). The cellulose source was filter paper which had been ground in a Wiley mill. Cellulose was determined chemically, by the method of Crampton and Maynard (1938), on the entire contents of the artificial rumen after the 36-hour hour fermentation period. Because only limited quantities of rumen fluid could be obtained from some of the calves, the amount of inoculum used averaged 90–100 ml. instead of the 140 ml. used by Burroughs.

Trial II

Sixteen male Holstein calves were employed to repeat, essentially, Trial I. Eight were placed on the milk replacement diet to which had been added 2 gm. of crystalline terramycin per 100 lb. of replacement.

Eight calves served as replacement-fed controls. Details of care and feeding of these animals were the same as in trial I. At the age of 6 weeks, 3 calves from each group were slaughtered in order that representative samples could be obtained from the rumen contents. The rumen contents were strained through 4 layers of cheesecloth and the expressed liquid was used to determine cellulose digestive power in the artificial rumen. The remaining 5 calves in each group were continued on exeperiment to 12 weeks of age. They received no milk replacement after the 8th week. No terramycin was fed by capsule, and therefore the experimental group received the antibiotic only until the 8th week of age. Rumen samples were obtained, by stomach tube, at the 8th week, and again at the 12th, for the purpose of determining cellulose digestive power of the fluid. Body weight and height at withers measurements were made weekly. Hay and starter consumption were recorded.

Trial III

In order to test further the effect of terramycin supplementation on the *in vitro* break down of cellulose in the artificial rumen, a third trial was initiated. Fifteen male Holstein calves, ranging in age from 8 to 10 weeks were divided into 3 groups of 5 each. The groups were given 10, 20 and 40 mg. of terramycin per 100 lb. of live weight, respectively. Administration was by capsule and lasted for 3 days. These calves had been raised on a diet of whole milk to 6 weeks of age, calf starter and hay. None of them had ever been fed an antibiotic. The terramycin used was in the form of the commercially available supplement. Prior to the initial dose rumen samples were obtained from each calf and tested in the artificial rumen for cellulose digestive power. After the antibiotic had been administered for 3 days, similar samples were obtained. In order to check on the ability of the rumen microorganisms to become re-established, 10 of the calves were held in the same surroundings for 6 days after cessation of terramycin supplementation when a third rumen sample was obtained and introduced into the artificial rumen.

Results

Growth data for the calves in these trials are presented in table 1. Weekly measurements were made, but for the sake of brevity only values for certain stages are reported. Calves fed terramycin supplement gained weight at an appreciably faster rate during the first 8 weeks than did replacement fed controls. The average difference at 8 weeks

between the 11 supplemented calves of groups 1, 2 and A and 11 controls (groups 2, 3 and B) was 15.7 pounds in favor of the former. During the first 8 weeks, they had an average daily gain of 1.14 pounds compared to .86 for the controls. Milk fed calves gained in body weight at a rate approximately equal to the terramycin fed calves. The continuation of antibiotic feeding past the 8th week to group 1 calves did not

TABLE 1. SUMMARY OF GROWTH DATA, TRIALS I AND II

Trial	Group	Treatment	No. of Calves	Increase in Body Weight Over Initial Lbs.			Increase in Height at Withers Over Initial Cm.		
				8 Wk.	12 Wk.	16 Wk.	8 Wk.	12 Wk.	16 Wk.
I	1	Terramycin to 16 wks.	3	65	117	169	11	15	20
	2	Terramycin to 8 wks.	3	68	119	166	10	14	18
	3	Terramycin started at 7 wks.	3	52	97	151	7	12	18
	4	Control—no terramycin	3	56	114	169	8	14	19
	5	Milk fed—no terramycin	3	65	123	177	9	14	18
II	A	Terramycin to 8 wks.	5	61	112	...	8	13	...
	B	Control—no terramycin	5	41	94	...	5	10	...
	C	Terramycin, slaughtered at 6 wks.	3	26[1]	...	...	5[1]	...	...
	D	Control, slaughtered at 6 wks.	3	23[1]	...	...	3[1]	...	...

1 Data for 3 calves at age 6 wk.

appear to stimulate growth in these animals over that of controls. Initiation of terramycin supplementation to group 3 calves at the 7th week did not increase the rate of growth between the 8th and 12th week; however, these calves gained quite rapidly from the 12th to the 16th week. Seperate analyses of variance were made on the data from Trials I and II. In Trial I weight gains in groups 1, 2 and 5 were significantly higher ($p<.01$) than gains in groups 3 and 4. Group 4 was probably lower due to poor initial gains during the first 8 weeks. In Trial II the supplemented group A showed a highly significant increase in body weight gain as compared to group B. This was due, apparently,

to a faster rate of gain by group A during the first 8 weeks. In the period between the 8th and 12th week, when group A calves no longer received terramycin, the control calves actually gained at a faster rate.

Gain in height at withers followed the same pattern as gain in body weight, with the exception that the terramycin fed calves tended to maintain more nearly the initial advantage after cessation of supplementation. Differences due to treatment again were highly significant, sta-

TABLE 2. STARTER AND HAY CONSUMPTION, TRIALS I AND II

Trial	Group	Treatment	No. of Calves	Starter Consumption Lbs./Calf		Hay Consumption Lb./Calf	
				1st 7 Wk.	7–16 Wk.	1st 7 Wk.	7–16 Wk.
I	1	Terramycin to 16 wks.	3	97	309	7	68
	2	Terramycin to 8 wks.	3	91	314	6	62
	3	Terramycin started at 7 wks.	3	65	298	4	55
	4	Control—no terramycin	3	54	309	10	95
	5	Milk fed—no terramycin	3	49	312	10	126
				1st 6 Wk.	6–12 Wk.	1st 6 Wk.	6–12 Wk.
II	A	Terramycin to 8 wks.	5	67	213	10	63
	B	Control—no terramycin	5	45	185	12	59
	C	Terramycin, slaughtered at 6 wks.	3	47	...	13	...
	D	Control, slaughtered at 6 wks.	3	43	...	13	...

tistically, with group 1 being higher, and group 3 lower, than all others in Trial I. In Trial II supplemented calves gained at a significantly faster rate during the first 8 weeks.

Hay and starter consumption varied a great deal between individuals; however, there were some group differences, as shown in table 2. Terramycin appeared to stimulate the appetite for starter, as shown by the fact that groups 1, 2, A and C all ate more starter than their respective controls. This was true especially during the first 6 or 7 weeks while the calves were still on completely *ad libitum* feeding of

starter. Hay consumption data showed no distinct differences except that the milk fed calves of group 5 ate exceptionally large amounts of hay throughout the trial.

The concentrations of thiamine and of riboflavin in the rumen samples obtained from the calves in Trial I are summarized in table 3. No consistent differences were found in thiamine levels. The data indicate a higher level of riboflavin for group 1 (fed terramycin), however, the addition of the antibiotic to the diet of group 3 calves at the 7th week failed to increase riboflavin levels in the rumen liquid. The data indicate that terramycin feeding had no adverse effect on rumen synthesis. No difference existed due to age at sampling between 6 and 16 weeks.

TABLE 3. LEVELS OF THIAMINE AND RIBOFLAVIN IN THE RUMEN FLUID FROM CALVES IN TRIAL I[1]

Group	Treatment	Thiamine μg./gm. of Dry Matter				Riboflavin μg./gm. of Dry Matter			
		6 wk.	12 wk.	16 wk.	mean	6 wk.	12 wk.	16 wk.	mean
1	Terramycin to 16 wk.	32.9	43.8	35.2	37.3	46.9	43.2	46.8	45.6
2	Terramycin to 8 wk.	31.9	32.8	33.4	32.7	40.5	48.4	33.1	40.7
3	Terramycin started at 7 wk.	25.6	27.4	26.8	26.6	35.8	30.5	33.0	33.1
4	Control—no terramycin	33.5	21.2	32.8	29.2	34.3	28.5	28.4	30.4
5	Milk fed—no terramycin	35.4	41.8	31.1	36.1	31.3	38.8	36.1	35.4

[1] Data are the mean of 3 calves per group.

Concentrations of thiamine averaged 6.6, 11.2 and 8.1 μg./gm. of dry matter respectively for replacement, starter and hay. Corresponding values for riboflavin were 24.5, 12.0 and 15.9 μg./gm. of dry matter. Levels of these two vitamins were higher in the rumen fluid than in the feedstuffs.

Cellulose digestion, as tested by means of the artificial rumen, was much poorer in those calves fed terramycin than in control animals. Table 4 presents the data obtained in Trials I and II. In Trial I the average values were 24.2% of the cellulose digested by rumen fluid from terramycin fed calves as compared to 67.4% from those not receiving terramycin. In this trial a highly significant difference existed due to treatment, with the two groups receiving the antibiotic being lower ($p<.01$) than those not receiving it. Coefficients of correlation were calculated between cellulose digestion and hay consumption by individual calves in Trial I. A highly significant correlation of 0.82

was noted between cellulose digestion at 16 weeks and hay consumption from 12 to 16 weeks. However, a non-significant correlation of 0.45 was found between cellulose breakdown at 12 weeks and hay consumption from 7 to 12 weeks. Six Trial II animals were slaughtered at the age of 6 weeks and fluid from the rumen contents tested in the artificial rumen. Supplemented calves were lower, as can be noted in table 4, however, the differences were not large, nor were the percentages digested high at this early age. At 8 weeks the terramycin fed calves exhibited a much lower ability to break down cellulose than did their

TABLE 4. CELLULOSE DIGESTION IN ARTIFICIAL RUMENS USING RUMEN FLUID

Trial	Group	Treatment	No. of Calves	Percent Cellulose Digested		
				at 12 wk.		at 16 wk.
I	1	Terramycin to 16 wks.	3	18.1		44.8
	3	Terramycin started at 7 wks.	3	20.4		13.3
	2	Terramycin to 8 wks.	3	75.5		41.5
	4	Control—no terramycin	3	81.9		62.1
	5	Milk fed—no terramycin	3	68.0		75.6
				at 6 wk.	at 8 wk.	at 12 wk.
II	A	Terramycin to 8 wks.	5	....	29.8	65.2
	B	Control—no terramycin	5	....	54.5	44.1
	C	Terramycin, slaughtered at 6 wks.	3	31.5	....	....
	D	Control, slaughtered at 6 wks.	3	34.6	....	....

controls. At 12 weeks, after supplementation had ended, they exhibited greater cellulose digestive power than did controls.

Table 5 contains a summary of the data obtained in Trial III. These calves were 8–10 weeks of age. After sampling, each was fed terramycin by capsule for 3 days, following which a second rumen sample was obtained. There was a pronounced drop in the amount of cellulose broken down by the rumen fluid after the calf had received the antibiotic, the mean values being 49.5% and 12.3% respectively. These differences were highly significant, statistically. Differences due to the level of supplementation were not large. Ten of the 15 calves were sampled 6 days after cessation of antibiotic administration as a check on whether the inhibitory effect was permanent. Calves checked indi-

cated that cellulose digestive power had returned to the pre-administration level.

Discussion

This experiment has demonstrated a growth stimulatory effect due to the inclusion of terramycin in the milk replacement diet at a level which afforded approximately 20 mg. of antibiotic per 100 lb. of body weight. This is in agreement with the results of other workers. This stimulus was accompanied by a greater intake of calf starter at an

TABLE 5. CELLULOSE DIGESTION IN ARTIFICIAL RUMENS, RUMEN FLUID FROM 8–10 WEEK OLD CALVES GIVEN TERRAMYCIN BY CAPSULE (TRIAL 3) [1]

Level of Administration	Percent Cellulose Digested		
	Before Administration	After Administration for 3 Days	6 Days After Administration Ceased
10 mg./100 lb. body wt./day	52.2	20.2	50.1 [2]
20 mg./100 lb. body wt./day	57.9	10.8	57.1 [3]
40 mg./100 lb. body wt./day	38.4	5.9	43.8 [2]

[1] Data are the mean of 5 calves at each level of administration.
[2] Mean of 4 calves.
[3] Mean of 2 calves.

earlier age. The results have not indicated any inhibitory effect of the antibiotic on levels of thiamine and riboflavin in the rumen fluid; presumably the microorganisms which synthesize these vitamins are not inhibited. The data indicate that the microorganisms which attack cellulose are inhibited by the presence of terramycin in the rumen. The effect seems more pronounced when the antibiotic is administered by capsule and thereby goes, presumably, directly into the rumen than when the antibiotic is included in the feed. This is indicated by the data of Trial II where differences were not as pronounced. In order to accept the thesis that the antibiotic inhibits cellulose digestion, one must accept the applicability of the artificial rumen technique to *in vivo* conditions. As a technique, it performed well in these trials. Control runs, using rumen juice from adult cattle, indicated a level of cellulose breakdown quite similar to those reported by Burroughs *et al.* (1950).

Some evidence is accumulating that antibiotics in the diet alter the

bacterial population of the intestinal flora. Rosenberg *et al.* (1952) reported a significant increase in enterococci in the intestinal flora of chicks fed terramycin. Using turkeys, Anderson *et al.* (1952) reported an increase in lactobaccilli, but no change in the other types studied. Sieburth *et al.* (1952) found that terramycin fed to turkeys resulted in a modification of the gram negative flora of the cecum. Marked reductions in the numbers of *Clostridia* in the intestinal tract of pigs, turkeys and chicks fed terramycin have been reported by Sieburth *et al.* (1951) and Elam *et al.* (1953); while Kiser *et al.* (1952) showed that terramycin is effective in low concentrations against experimental infections of mice, using seven different species of *Clostridia*. Finally, Cuff *et al.* (1951) noted a decreased anaerobe count of feces of weanling pigs fed various antibiotics, including terramycin.

The reduction in the ability of the rumen microorganisms to digest cellulose noted in the present experiment could be explained on the basis of evidence from the above citations. Since most of the rumen microorganisms are anaerobic, it seems possible that some of those which attack cellulose could be inhibited. Additional information on this aspect would seem desirable. From a practical standpoint, the data appear to indicate that terramycin supplementation of milk replacement rations of young calves is desirable as a growth stimulator; but that as the animal grows older, and depends more on rumen digestion of fibrous feeds, one should refrain from such supplementation.

Summary

The addition of terramycin to a milk replacement diet for young calves stimulated growth significantly, as measured by body weight gains and increase at height at withers. Supplemented calves consumed more concentrates, and at an earlier age.

There was little apparent effect on the concentrations of thiamine and riboflavin in the rumen fluid obtained from these calves at ages 6, 12 and 16 weeks. Levels of these vitamins were considerably higher than in the feed afforded the calves.

Terramycin in the milk replacement, or administered by capsule, lowered the *in vitro* breakdown of cellulose by microorganisms of the rumen fluid, as measured in an artificial rumen.

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DIGESTION AND NUTRIENT-BALANCE STALLS FOR STEERS [1]

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University of Illinois [4]

A COMMON criticism of digestion and nutrient-balance studies made with steers is that intake of feed is abnormally low and erratic. This lack of appetite is in many cases attributable to the animals being too tired to eat resulting from the close confinement made necessary by the very nature of the equipment used.

A detailed description of the construction of inexpensive metabolism units designed to combine efficient urine and feces collection with a more comfortable stall for restraining steers during the collection period is presented in this paper. The units incorporate many of the features of the equipment described by Briggs and Gallup (1949) and Hobbs *et al.* (1950).

Description of Stalls and Equipment

A perspective of a dual-unit stall, together with some construction details and measurements, is shown in figure 1. The units were constructed as dual-units for increased stability and conservation of floor space.

The floor of each unit was constructed of 1 x 6 inch creosote treated softwood boards. This type of flexible flooring was used in preference to heavier lumber, in order that there would be some "give" when the animal changed position, and thereby help prevent fatigue. Strips of heavy corrugated rubber matting were placed longitudinally on top of the floor boards in an attempt to lessen fatigue further and also to strengthen the floor without eliminating the "springiness".

It was believed that an animal would be more comfortable and content and thus likely to eat better if its head was not restrained in a stanchion. With this in mind, small steel retaining chains were placed across the rear of each unit at a level which would be just above the hocks of the animal. This method of restraint proved satisfactory as

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it permitted considerable freedom of movement, yet kept the steers in place. Because the steers were kept as far back towards the rear of the stall as possible, few droppings came in contact with the chain. When standing the steers' heads were over the feed box, preventing spillage. When lying down the most common position of the steers' heads was for them to be lying back over their sides.

The feed boxes were fastened on runners so that they could be

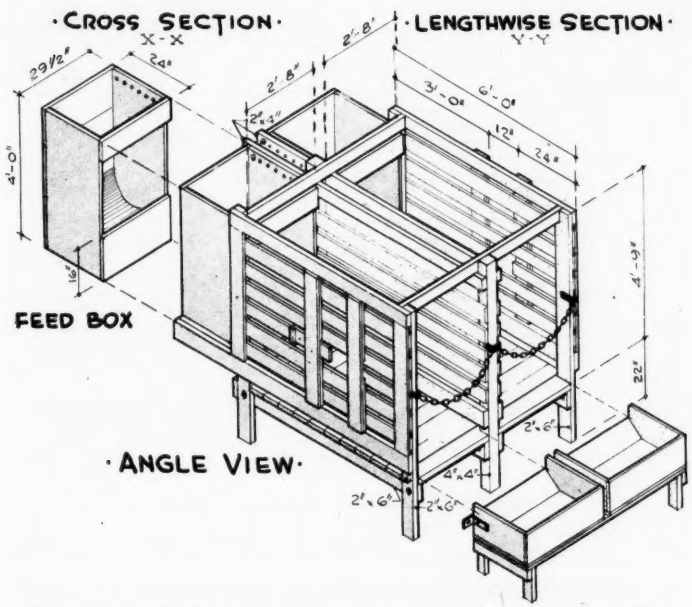

Figure 1. Detailed drawing of complete dual-unit metabolism stalls.

moved backwards or forwards to regulate the length of the unit as shown in figure 1. The bottom of each feed box was made of one continuous piece of smooth sheet metal to eliminate corners where feed ordinarily accumulates. The feed boxes were large as shown in figure 2. Consequently, very little feed was lost. The large door in the front of the feed box enabled the feeder to place a large volume of feed in it at one operation. Steers were watered by pail, placed in the feed box for a short period three times each day. The attendant stood close by during the period of watering to prevent spillage and to

replenish the water supply. A metered, automatic fountain, located at either end of the feed box would be a real improvement, so far as watering is conccerned.

Feces boxes were attached to the rear of the units and supported by a separate small, portable platform as shown in figure 1. These boxes were fitted to the unit with a beveled edge to prevent loss of feces at the junction of the feces box and unit.

Urine collections were made via a rubber funnel and a rubber tube in a 10-liter pyrex bottle located beneath the floor of each stall. The rubber funnel was constructed of heavy-duty rubber truck tire tubing. This material was cut and vulcanized to form a funnel approximately

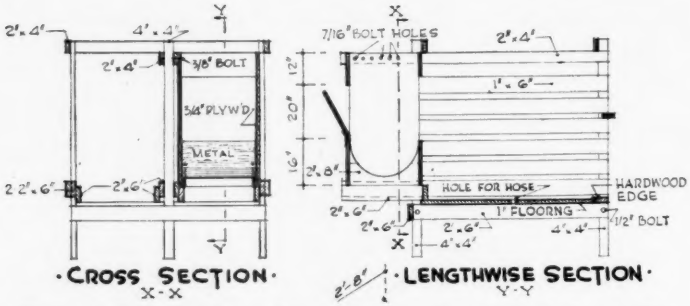

Figure 2. Cross section and lengthwise section of metabolism stalls.

8 inches in diameter at the top and 12 inches in depth. The bottom of the funnel was vulcanized to one-half of a bicycle-tire tube. A heavy wire ring was vulcanized into the top rim of the funnel. A rubber loop was vulcanized to the urine tube about 12 inches from the bottom end. When the steer was in position in the metabolism unit the rubber loop was attached to the neck of the pyrex collection bottle. This prevented the animal from pulling the tube from the collection bottle.

The funnel was held snugly against the belly of the steer by a harness as shown in figure 3. This harness was constructed of 4-inch moisture and mildew-proof webbing. The two girth straps were joined on the ventral side by short transverse pieces to form an opening approximately six inches square. The top of the rubber funnel was attached to loops along the edges of this opening in the harness. A breast strap was used to help eliminate lateral slipping. On some animals the breast strap had a tendency to fall below the points of the shoulders onto the

brisket. This was overcome by attaching a piece of soft 2-inch webbing (not shown in figure 3) to the breast strap at about the shoulder point. This piece of webbing was then passed over the crest of the steer and buckled to the breast strap on the other side. To facilitate adjusting, all buckles were located along the same side of the animal. Openings were made in the outside of each stall to facilitate initial placement

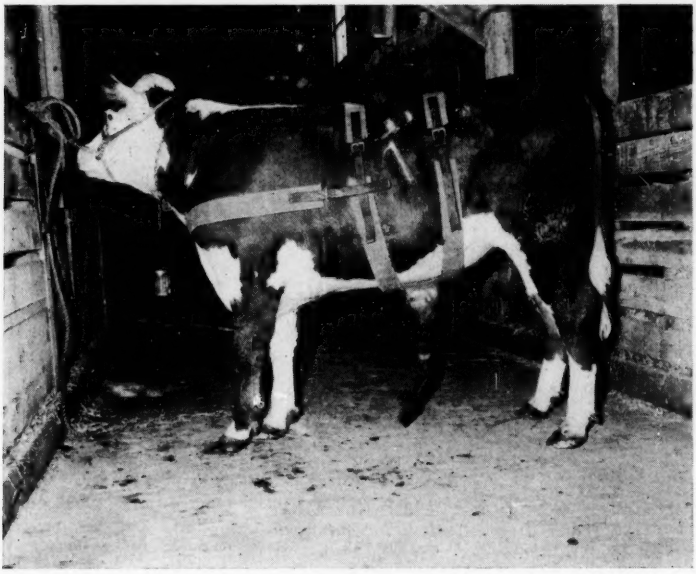

Figure 3. Side view of steer with urine collection apparatus in position.

of the funnel and adjustment of the harness. Figure 4 shows three dual-units with feces boxes and covered feces storage containers in position for use.

Eight to nine hundred pound yearling steers, kept on collection for periods as long as 15 days, performed normally, as indicated by feed and water intake and by weight gains.

Summary

Equipment is described for use in digestion and nutrient-balance studies with steers. The equipment was designed to facilitate operation,

to provide comfort for the animals and to permit accurate balance studies.

Figure 4. View of three dual-unit stalls ready for use.

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THE EFFECTS OF AGE UPON CALCIUM UTILIZATION AND MAINTENANCE REQUIREMENTS IN THE BOVINE [1]

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IT is generally recognized that as an animal grows older, there is less efficient utilization of ingested calcium. It has not been clear, however, whether this decreased efficiency with age is due to poor absorption from the gastrointestinal tract or poor retention by the tissues or both. The fecal calcium includes not only the unabsorbed portions from the feed, but also that which has been absorbed and re-excreted, and that lost from the body stores. Balance measurements of calcium absorption by conventional procedures yield only net loss or gain and do not permit differentiation between unabsorbed and metabolized excreted calcium. This has made it virtually impossible to measure the *true* digestibility coefficients for feed minerals until the use of radioisotopes made possible a direct means of differentiation between the endogenous and exogenous fractions in normal animals. Hansard *et al.* (1950, 1951a, 1952) presented evidence that in young growing cattle there was a greater retention of ingested radiocalcium than of stable calcium as measured by conventional balance methods, and suggested the possibility of calculating endogenous calcium from this difference. Hansard *et al.* (1951a) and Hansard (1952, 1953) extended this concept in studies involving the quantitat e partition of calcium in the gastrointestinal tract of cattle and separated the endogenous and exogenous fecal calcium fractions by the integration of concurrent chemical and radiocalcium balance studies following oral and intravenous administration of the isotope to paired steers. This comparative procedure made it possible, therefore, to measure endogenous calcium by an isotope method that was independent of the isotope dilution principle. The results obtained, however, were in agreement with similar data procured by the isotope dilution method (Visek *et al.*, 1953). Neither of these procedures give information as to the pathway by which the endogenous calcium reaches the feces, but do indicate an overall measure of the loss from the body.

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This paper presents the effects of age upon calcium absorption and excretion in the bovine under controlled conditions with the use of radiocalcium. The significance of fecal calcium partition and the quantitative estimation of endogenous calcium, *true* digestibility and maintenance requirements of cattle as a function of age are discussed.

Experimental

Thirty-four selected Hereford cattle ranging in age from 10 days to 190 months are included in this study. They were maintained on calculated adequate rations previous to and during the experimental period. The calves, including the 30 day old group, were fed fresh milk from a pail. The six month old calves were fed a ration of 6 pounds commercial calf chow meal and hay and water *ad lib*. The older animals were selected from the farm herd and placed on experimental rations two to six months prior to the balance period. The ration consisted of 4–6 pounds of ground yellow corn, 0.5 pounds of wheat bran fortified to contain 1500 I.U. of vitamin D as irradiated yeast and lespedeza—orchard grass hay fed *ad lib*.

Following the conditioning period, the animals were placed in individual metabolism units as previously described by Hansard (1951) for the quantitative separate collection of urine and feces. After the animals had become adjusted to the units and were on a constant feed intake, they were given orally or intravenously a single dose of radiocalcium (Hansard *et al.*, 1951) and concurrent seven day chemical and radioisotope balance studies were started.

Representative fecal and urine samples were taken in duplicate or in triplicate at regular intervals from the quantitative collections. Ration constituents and weigh-back were carefully ground and sampled for analysis and intake calculations. Total ash and phosphorus were determined by standard methods of procedure. Analysis for total calcium and radiocalcium were carried out as described by Comar *et al.* (1951).

Results and Discussion

Age and Calcium Balance

A summary of the calcium intake and excretion values for cattle at the different ages is given in table 1. For convenience of analysis and comparative presentation these thirty-four animals were lotted into seven age groups and the data, with the mean $\pm$ the standard deviation, tabulated (Dean and Dixon, 1951). The dietary calcium and phosphorus intake and ratio for all groups approximated the recommended

TABLE 1. SUMMARY OF ANIMALS USED AND RESULTS OF CONCURRENT CALCIUM-RADIOCALCIUM BALANCE STUDIES[1] WITH CATTLE AT VARIOUS AGES

Age Groups	Age of Animals (months)	Number of Animals	Average Weight (pounds)	Total Calcium[4] (gms./day)		Percent Calcium Intake Excreted[3]	Percent Calcium 45 Dose Excreted[3]	
				Intake	Excretion[3]		Oral	Intravenous[4]
10-days	0.3	3	78±7[2]	8.8± 0.9	0.6±0.2	7.2±3	3.0±1	2.0±0.1
30-days	1.0	3	146±32	7.4± 0.8	1.2±0.6	16.6±9	6.5±3	1.0±0.1
6-months	6.0	5	393±50	20.8± 2.	15.8±2.5	76. ±5	62. ±2	8.0±2
Yearlings	15–24	6	660±60	22.2± 6.	19.2±7.	86. ±9	70. ±7	12. ±2
2-years	25–34	8	829±120	26.6±10.	21.8±8.	82. ±12	70. ±8	15. ±2
Mature	36–73	5	998±200	21.5± 3.	22.1±2.	103. ±10	70. ±4	17. ±3
Aged	144–190	4	936±70	18.8± 2.	24.2±4.	128. ±14	83. ±4	25. ±3

[1] Data calculated from individual 7-day balance studies.
[2] Mean±standard error of the mean.
[3] Includes only fecal excreted calcium.
[4] Total calcium values are averages for all animals; about 2/3 of animals were dosed orally and 1/3 intravenously with tracer levels of Calcium 45 choride.

level (Maynard, 1947). It is of interest to note that the excretion of calcium increased with increasing age. Positive calcium balance was largely maintained throughout, including the mature group of animals, but in those animals over 36 months of age the calcium and phosphorus balances were negative. In another study when the rations of 12 year old cows were supplemented with one hundred grams of calcium phosphate in capsules on the first of a seven day balance study, or when it was added at the rate of forty grams per day for five consecutive days of the balance period in four trials with two cows, the animals still remained in negative calcium balance. This would indicate that there was very little absorption in aged animals, even with large amounts of available calcium, and that oral therapy of additional calcium, even when adequate phosphorus was present, did not compensate for the loss of calcium from the body.

Age and Radiocalcium Excretion

Simultaneous radiocalcium balance studies (table 1) with these animals substantiated the findings relative to decreased utilization efficiency with increasing age as demonstrated by the total calcium values. Following oral administration of labeled calcium, it was observed that the total excretion in the urine was low, averaging for all ages less than 0.5 percent of the dose. The fecal excretion, however, ranged from 3 percent in the young calf to 62 percent in the six month old calves, and increased to 83 percent in the 160 month old animals. Urinary excretions of labeled calcium were slightly higher following intravenous administration than after ingestion, but fecal excretions were lower. In the very young animal fecal excretion was about the same for both methods of administration. The fecal excretion of intravenous calcium 45 increased rapidly with age from 8 percent in the 6 month group to 25 percent in the aged animals. The kinetics of this movement through the tract and excretion as a function of age will be discussed in another paper.

Fecal Calcium Partition and Its Significance

Since the principal pathway for calcium excretion is by way of the feces, a quantitative estimation of the partition of calcium in the gastrointestinal tract is of considerable importance for the interpretation of data procured from radioisotope tissue distribution studies, the calculation of endogenous fecal calcium, *true* digestibility and main-

tenance requirements; and the results may be employed in the determination of net dietary calcium requirement at the different ages.

Methods and techniques for the estimation of the excreted calcium and its partition within the gastrointestinal tract of steers (Hansard *et al.*, 1951a) and rats (Hansard, 1953) have been previously presented and reviewed. Briefly, it consisted essentially of integrating the excretion data from animals dosed orally with that of similar animals receiving a single intravenous dose of labeled calcium and employing the seven day balance figures to calculate the source of the fecal calcium. For illustration the schematic diagram presented in figure 1 shows the procedure and basis for the calculations of exogenous and endogenous fecal

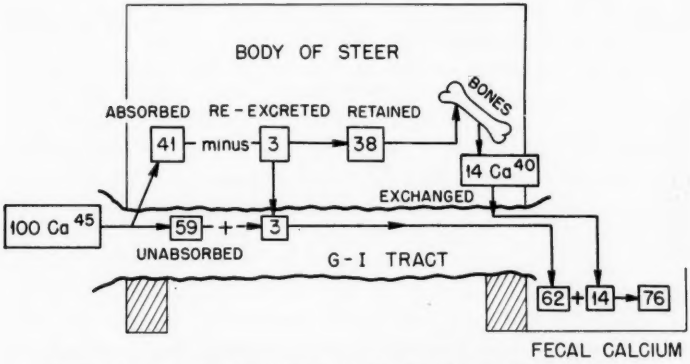

Figure 1. A schematic diagram of the partition of calcium in the gastrointestinal tract of a six month old bovine.

calcium, unabsorbed, absorbed, and the absorbed—re-excreted calcium in the feces of a 6 months old steer. It was assumed at the outset that tracer levels of calcium 45 chloride and the dietary calcium were equally absorbed from the tract and that the labeled calcium which reached the blood was secreted into the tract to the same extent as that of an intravenously administered tracer dose of radiocalcium.

Conventional balance studies with these steers (table 1) indicated that when 100 units of stable calcium was ingested by the six month old animals 76 percent of this calcium intake was excreted in the feces. The concurrent radiocalcium balance figures (table 1) showed that only 62 percent of a single oral dose of the isotopes was excreted. Results from the intravenous radiocalcium balance studies, however, indicated

that approximately 8 percent of the calcium 45 ions reaching the blood appeared in the feces. It was assumed, therefore, that when the animal ingested 100 units of calcium-45, 62 percent of this would be excreted, and then that which was absorbed (A) was calculated as follows:

$$(100-A)+(0.08)A=62$$
$$A=41$$

This means that 41 percent was absorbed into the blood of the animal. However, 8 percent of that calcium reaching the blood ($41\times.08$) or 3 units were re-excreted into the gastrointestinal tract (table 1) leaving (41—3) 38 units retained in the animal body which were eventually deposited by accretion or exchanged into the bones. It is calculated

TABLE 2. THE PARTITION OF CALCIUM IN THE GASTROINTESTINAL TRACT OF CATTLE OF VARIOUS AGES [1]

Age Group	Percent of Calcium Intake				Fecal Calcium From Body Stores	
	Absorbed	Unabsorbed	Absorbed Re-excreted	Retained	Percent [3]	Grams [4]
10-day	99±0.5	1.0± .01 [2]	1.0±0.2	98.±0.5	3.± 2	0.3
30-day	98±0.4	2.0±0.2	1.0±0.3	97.±0.3	10.± 5	0.7
6-months	41±0.4	59. ±0.5	3.0±0.4	38.±0.4	14.± 3	2.9
Yearlings	34±4.0	66. ±2.0	3.0±0.4	31.±3.0	16.± 8	3.6
2-years	36±7.0	64. ±7.0	5.0±1.0	31.±6.0	13.±10	3.2
Mature	34±8.0	66. ±3.0	6.0±1.0	28.±2.0	33.± 7	7.1
Aged	22±4.0	78. ±4.0	6.0±1.0	16.±2.0	45. ±9	8.5

[1] Calculated from date in table 1.
[2] Mean±standard error of the mean.
[3] Calculated as percent of dietary calcium in feces originating from sources other than the feed. This figure plus the absorbed and re-excreted values equals to the endogenous fecal calcium.
[4] Calculated as total grams per animal per day lost from body stores.

further that 100 minus the absorbed fraction equals the percent of ingested calcium that was unabsorbed. The total fecal calcium minus the unabsorbed fraction, plus the absorbed and re-excreted calcium 45 [76—(59+3)] equals that calcium lost from the body stores. The calcium retained then minus that exchanged and/or lost from the body (38—14) would indicate that 24 percent or 5 grams of the ingested calcium was actually deposited daily in the animal body.

In brief, then when 100 units of stable calcium was ingested by six month old steers 76 percent was excreted. Of the calcium entering the tract 41 percent was absorbed, but 3 percent was re-excreted leaving 38 percent in the body for deposition and/or exchange. The 14 percent excreted from sources other than the feed plus the 3 percent absorbed but re-excreted made up the endogenous or the metabolic fecal calcium.

The results of this study are summarized in table 2 and show the variations in the different fractions with increased age and weight of the animal. In the first place it is observed that absorption decreased from 99 to 41 to 22 percent in the 10 day, 6 month and aged animals respectively. It was of particular interest that the unabsorbed calcium increased from one in the 10 day old calf to 78 percent in the aged cow. The calculated amount absorbed and subsequently re-excreted into the tract was 1 and 6 percent for the young and the aged animals respectively. Since calculations were made from net excretion values, it is impossible to determine the differences due to "recycling" of the re-excreted calcium. However, it would appear that this was a contributing factor to the high net calcium absorption in young animals. The total calcium actually retained decreased from approximately 98 in the 10 day old calf to 28 in the mature animal and downward to 16 percent in the aged cattle. There appeared to be little difference in the retained fraction in animals from 15 to 73 months of age. The calcium in the feces originating from body stores increased with age of animal. The loss was small during the first few months of life, but increased rapidly to approximately 3 grams at 6 months with little change in total calcium then until maturity. After maturity the loss of calcium from the body stores increased to about one-third of the dietary intake and in the aged animal it represented nearly one-half or 8.5 grams daily.

The increased loss of calcium from the body and the high percentage of unabsorbed calcium excreted with increased age help to explain the negative balances encountered after maturity was reached. Furthermore, these findings strengthen the evidence that in addition to poor absorption there is decreased retention with age by the skeletal tissues themselves. It has been indicated (Hansard, 1953) that calcium absorption as well as utilization by the animal may be goverened by internal mechanisms. How these mechanisms control the absorption from the intestines or regulate the deposition and subsequent fixation of the absorbed calcium into the skeletal tissues, however, require further study. Renal function is probably not involved because of the relative small portion of the calcium excreted by this route.

Endogenous Fecal Calcium and True Digestibility

In table 3 a summary is presented of the daily endogenous fecal calcium, the apparent and the *true* digestibility as a function of age of the animal. It is of interest to note that the daily endogenous fecal calcium increased in a regular manner with increasing age and weight

of the animal. The range in values from 3.3±0.6 to 5.4±1.8 in grams for the 6 month to two year old groups indicates that there was little change from the age of sexual maturity to maturity. However, after the animal reached maturity the endogenous loss increased and it was apparent that in the aged animals this loss exceeded the absorption from the tract (table 2). There was little difference between the apparent and *true* digestibility values for calcium at the younger ages but an increasing difference with increasing age. At maturity the apparent di-

TABLE 3. THE EFFECT OF AGE UPON ENDOGENOUS FECAL CALCIUM AND DIGESTIBILITY OF CALCIUM IN NORMAL RATIONS FOR CATTLE

Age Group	Daily Endogenous [1] Calcium (grams)	Apparent Digestibility [2]	True Digestibility [3]
10-day	0.41±0.2	93± 3.5	98±1
30-day	0.97±0.3	84± 9.0	98±1
6-month	3.3 ±0.6	24± 2.3	41±1
Yearlings	4.3 ±1.3	14± 3.1	34±3
2-years	5.4 ±1.8	17± 4.0	36±6
Mature	8.0 ±1.5	−3± 5.0	34±8
Aged	9.2 ±2.4	−28±14.0	22±4

[1] Endogenous fecal calcium calculated from the 7-day concurrent chemical and radiocalcium balance studies; includes that calcium lost from the body stores plus that absorbed from the tract and subsequently re-excreted.

[2] Apparent digestibility calculated as $100-\left(\frac{\text{Fecal Calcium}}{\text{Calcium intake}}\times 100\right)$.

[3] True digestibility calculated as

$$\frac{(\text{Ca intake}-\text{Fecal Calcium}+\text{Endogenous Fecal Calcium})}{\text{Calcium Intake}}\times 100.$$

gestibility figures indicated that none of the ingested calcium was being stored, whereas the *true* digestibility values indicated that a third of it was being utilized. The aged animals, despite their ability to utilize a fourth of the dietary calcium, were still losing an excess of calcium from the body stores and were in negative calcium balance. It is realized that the nature of the ration may have been a contributing factor to the high degree of utilization in the young calves on a milk diet. However, the rations used for animals 6 months of age and older were essentially the same, and within these groups, age must have been the primary factor in the decreased utilization of the dietary calcium available.

The measurement of endogenous fecal calcium makes it possible to determine experimentally the *true* digestibility of calcium under normal

feeding conditions. Before considering the application of this simple procedure it is of interest to point out some of the factors known to influence the endogenous calcium. It is indicated in this study that these values for animals of the same age and nutritional status are relatively constant and that from six months to maturity the effects of age are not great. Hegsted *et al.* (1952) in studies with man and Hansard *et al.* (1951) with cattle and with rats (Hansard, 1953) have indicated that a low calcium status gives a low endogenous fecal calcium value. However, it has been demonstrated (Visek *et al.*, 1953) that the addition of excess dietary calcium for short periods of time does not materially affect endogenous values. The apparent constancy within groups of known age and nutritional status makes it possible to measure the utilization of calcium from the various dietary sources with animals of any age. Endogenous fecal calcium may be determined concurrently either by comparative balance studies or by the isotope dilution technique. Experimental rations or supplements to be tested for *true* digestibility may then be incorporated and fed in conventional balance studies, and corrected for endogenous loss to give the net utilization values. It is emphasized that the test ration must approximate the normal calcium intake and should contribute the greater part of the dietary calcium being fed.

Estimation of Maintenance Requirement

Since the metabolic fecal calcium in ruminants makes up the major portion of the total calcium lost from the body, the maintenance requirements of cattle are essentially equal to the endogenous fecal calcium values. Requirements for growth, pregnancy and lactation may be estimated directly by product analysis. Therefore, the summation of these and the maintenance requirements should equal the net calcium requirement. The use of these concurrent isotope and chemical balances thereby permit a *direct* estimation of dietary calcium utilization in animals under the various conditions which in turn may be used to calculate the dietary requirements.

The high percentage retention of dietary calcium observed in young normal growing animals has been interpreted by some investigators to mean that there is no integral requirement of this element for maintenance. However, as is noted in table 3, a 10-day old animal has a loss of nearly 0.5 grams calcium per day and there is evidence of a substantial loss of endogenous calcium at all ages. If this loss can be considered as a measure for such requirement (Mitchell, 1947), it is

obvious that even young rapidly growing animals do have an endogenous loss of calcium that is not suppressed during growth and consequently do have a maintenance requirement for calcium. It is indicated further that the calcium requirement for maintenance is greater, especially after six months of age, than that for growth itself.

In table 4 it is of interest that the quantity, milligrams of endogenous fecals calcium per kilogram of body weight, was not significantly affected by age. Consideration of the values at 10 days and in the aged animals indicate a trend toward an increase. However, after 30 days of

TABLE 4. THE EFFECTS OF AGE UPON CALCIUM MAINTENANCE REQUIREMENTS OF CATTLE

Age Group	Animal Weight Kilogram	Daily Endogenous Calcium (mg./kg.)	Calcium Maintenance Requirement (grams per day)[1]	
			Per Animal	Per 100 Pounds Body Weight
10-day	35±1	11.8±1	0.43	0.55
30-day	66±14	14.4±3	1.0	0.68
6-months	182±26	18.0±2	8.0	2.00
Yearling	300±25	14.4±4	12.6	1.90
2-years	376±54	16.7±3	15.1	1.90
Mature	453±90	18.0±5	23.5	2.35
Aged	425±15	21.3±4	41.8[2]	4.46[2]

[1] $\frac{\text{Calculated as grams endogenous fecal calcium}}{\text{true digestibility}} \times 100.$

[2] See reference to text regarding animals in negative calcium balance.

age they were relatively constant. The use of more animals will be necessary to verify the significance of these small differences.

The calcium maintenance requirements were calculated from the endogenous and true digestibility values. For cattle six months of age the endogenous loss averaged 3.3 grams per day, and the *true* digestibility values showed an average utilization of 41 percent, indicating a daily calcium requirement for maintenance of 8 grams of dietary calcium per day or 2 grams per hundred pounds body weight. The calculated requirement for normal animals on a normal ration at the various ages are tabulated in table 4. There was a marked increase in the requirement sometime between 30 days and six months of age as indicated by values of 0.68 and 2.0 grams per day per 100 pounds body weight respectively.

There was little change thereafter to maturity. In the aged animals the high endogenous loss and the poor absorption and utilization of the dietary calcium increased the calculated requirement to nearly 5 grams per hundred pounds body weight. The constancy of the requirements after six months of age is of special interest and is a reflection of the endogenous loss and true digestibility previously discussed. The high estimated requirement for the aged animals may be considered to have little physiological significance since calculations are based upon true digestibility values of a normal dietary calcium intake level.

Summary

Concurrent chemical and radiocalcium balance studies were carried out with thirty-four Hereford cattle ranging in age from 10 days to 190 months. Absorption and/or *true* digestibility values were greatest in young animals, decreased rapidly to sexual maturity then more slowly to maturity, and again decreased in the aged animals.

Daily endogenous fecal calcium increased with increased age and body weight from 0.42 grams at 10 days to 3.3 at 6 months to 8 grams at maturity. The quantity, milligrams per kilogram body weight of endogenous fecal calcium, was remarkably constant from one month of age to maturity. However, the low level in 10 day old animals and the slightly higher level in aged animals indicated a trend toward an increase with age.

Maintenance requirements per 100 pounds body weight calculated from the endogenous and *true* digestibility values ranged from 0.5 grams at 10 days to 2 grams at six months and remained relatively constant to maturity.

Procedure described should be useful for the estimation of the *true* digestibility of calcium from the various organic and inorganic sources with animals of different ages under various experimental conditions.

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A STUDY OF PASTURING AND SOILING ALFALFA WITH BEEF STEERS [1]

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SOILING as a means of feeding green forage to livestock has been practiced for many years. As early as 1814 the soiling system was used in Massachusetts (Stewart, 1895). Its main use, however, has been to supplement pasture during periods of limited feed production. At such times some high-yielding crop has been grown specifically for soiling purposes. Depending upon the type of pasture and the crop available for soiling, the economy of such a program varied considerably. For example, Otis (1900) reported that when a prairie and mixed grass pasture was compared to alfalfa, oats, corn, cane and Kafir-corn that had been soiled, the yield from soiling was over four times at great as that from pasturing. Tretsven (1933), on the other hand, concluded that when soiling crops were substituted for good irrigated pasture, the net return per acre was decidedly in favor of the pasture. Although there are other studies on soiling crops, the authors know of no experiment in which pasturing has been compared directly to soiling the same type of forage. It has usually been true that the cost of soiling has limited the practice. Recently, however, interest has been revived, particularly in the alfalfa-growing regions of the West, where soiling has been used to replace, rather than supplement, pasturing. The use of modern labor-saving forage harvesting and handling equipment may make soiling an economical replacement for pasturing.

Meyer *et al.* (1953) studied the beef produced from soiling alfalfa and the effect of adding certain supplements to this green forage. Outstanding production was obtained during the season of the year when alfalfa growth is normally slow. No direct comparison, however, was made of the beef production from pasturing.

Because there is a lack of information on production obtained from soiling a forage crop as compared to pasturing the same crop, an experiment was designed to obtain the comparative information on alfalfa, a forage crop of great importance, especially in the western part of the United States.

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Experimental

The test was conducted in the Imperial Valley in the desert area of California, a region characterized by a long, hot growing season and a short, relatively mild winter. The area is well adapted to raising alfalfa and winter pasturing of cattle. The growing of alfalfa depends entirely upon irrigation, since annual rainfall is only two to three inches, and rain occurs so infrequently as to be of little value.

The alfalfa fields used in this study were renovated, reseeded, fertilized with 46 pounds of phosphate per acre, and seeded with barley on October 1, 1952. This procedure assures this area of winter pasture in case of a heavy frost. This particular winter, however, was warm and the alfalfa continued to grow throughout the course of the experiment. During the months of January, February, and March the forage contained 68, 24 and 27 percent barley forage respectively. During the latter half of the study the forage was made up entirely of alfalfa.

On December 30, 1952, forty good-quality, yearling Hereford steers, weighing an average of 544 pounds, were divided into four lots of ten head each. One lot was then assigned to each of the following treatments: rotation grazing, strip grazing, green soiling and wilt soiling. The area to be used for rotation grazing was divided into four fields, the steers being kept in a field from 8 to 12 days and then rotated to the next field. Three irrigations were applied between grazings. As forage production increased during the season, the size of the four fields was reduced to allow for maximum utilization of the forage. The animals being strip grazed were given an area which they would graze completely in 24 hours. Each day they were given a similar area. Strip limits were established by electric fences which were moved each day. As in the case of the rotation-grazed fields, three irrigations were applied between grazings. The two soiling lots were fed chopped forage in the dry lot twice daily. During the first three months sufficient green forage was harvested each evening for the evening feeding and for the feeding on the following morning of the lot on green soiling. As the weather became warmer, forage was harvested twice daily just prior to each feeding. Forage for the wilt-soiling lot was mowed, allowed to wilt, raked and chopped. The time required to wilt the alfalfa varied from a few hours to two days depending upon weather conditions.

Records were kept of the area pastured or harvested for soiling plus that growing for future use in the experiment. To control scouring and bloat each lot received a small amount of oat hay twice daily. Accurate records were kept of the forage consumed by the two soiling lots, and

samples for moisture determination were taken from the forage given these two lots every three days. The average dry matter content for the forage fed the green soiling lot varied from 20.7 to 27.2 with a mean of 25.5 percent. The dry matter of the wilted forage varied from 34.2 to 50.9 with a mean of 43.5 percent. Moisture determinations were

TABLE 1. SUMMARY OF RESULTS

Treatment	Lot 1 Rotation Grazing	Lot 2 Strip Grazing	Lot 3 Green Soiling	Lot 4 Wilt Soiling
Number of steers	10	10	10	10
Number of days on experiment	168	168	168	168
Initial weight, lbs.	547	541	547	541
Final weight, lbs.	850	861	870	840
Average daily gain, lbs.	1.80	1.90	1.92	1.78
Feed consumption per head per day:				
As fed:				
Forage, lbs.	...	...	60.2	34.8
Hay, lbs.	3.3	3.7	2.5	2.5
Dry basis:				
Forage, lbs.	...	...	15.2	15.0
Hay, lbs.	3.0	3.3	2.2	2.2
Dry matter required per 100 pounds gain, lbs.	...	...	906	966
Beef production from forage:				
Total, lbs.	2531	2593	2872	2653
Per acre, lbs.	417	580*	704**	568*
Increase over rotation grazing:				
Pounds	..	163	287	151
Percent	...	39	69	36
Acres used [1]	6.07	4.47**	4.08**	4.67**
Dry matter production per acre, tons [2]	...	...	6.0	5.4

[1] Includes area grazed or used for soiling plus those growing for future grazing or soiling.
[2] Includes only that area actually used for soiling but does not include area growing for future use.
* Significant at 5% level when compared to rotation grazing.
** Significant at 1% level when compared to rotation grazing.

also made on all refused feed so that dry matter consumption could be calculated.

All animals were individually weighed every 28 days after a 10-hour stand without feed or water. The experiment was terminated on June 16, 1953, after 168 days, with the animals weighing an average of 855 pounds.

Results and Discussion

Table 1 summarizes the results of the experiment. There were no significant differences among the gains of the four lots. For animals on

a roughage diet all gains were excellent, and for the first three months of the test the average daily gain of all animals was over two pounds.

There was no difference in dry-matter consumption of the two soiling groups, even though the green-soiling lot consumed an average of approximately 25 pounds more forage each day. Bloat was never a problem in any of the four lots, although the two pasture lots required more dry hay to maintain firm feces and to preclude the danger of bloat. This can probably be explained by selective grazing of the more succulent portions of the plants by the pasture lots.

The values given in table 1 for beef production per acre have been corrected for the oat hay consumed and represent that produced from the forage alone. Although no significant differences in weight gains were observed, beef production per acre did show significant differences. Because of the smaller acreage required for the strip-grazing and soiling lots, their beef production per acre was greater than that produced by rotation grazing. The acreage used by the four lots includes the area actually pastured or harvested plus that growing for future use in the experiment and is the average for the six 28-day periods. The beef produced per acre by green soiling was 69 percent greater than that from rotation grazing, a highly significant difference. Production from strip grazing and wilt soiling, while less than that from green soiling was significantly greater than that from rotation grazing. The least difference required for significance between any two lots at the 5 percent level is 138 pounds. The difference between green and wilt soiling is 136 pounds and thus closely approaches significance. Observations made during the experiment lead the authors to believe that this is a real difference. During the raking and hauling of the wilted forage, considerable loss of leaves and some of the finer stems occurred. This loss undoubtedly resulted in both lower production of forage per acre and feed of lower nutritive value. The lower yield per acre from wilt soiling is shown by the 5.4 tons of dry matter produced per acre harvested, as compared with 6 tons produced by green soiling.

Tables 2 and 3 present the data on beef production and acreage used by periods. The data in table 2 show that production from rotation grazing was consistently below that of the other three lots. Only during period 5 was production from rotation grazing as high as that from strip grazing and wilt soiling, and never did it approach that of green soiling. It is interesting to note the differences in the number of acres required by the four lots as presented in table 3. Rotation grazing consistently required more acreage than green soiling and seldom required

TABLE 2. BEEF PRODUCED PER ACRE PER 28-DAY PERIOD FROM FORAGE

Period No.	Dates	Lot 1 Rotation Grazing	Lot 2 Strip Grazing	Lot 3 Green Soiling	Lot 4 Wilt Soiling	Means
		pounds	pounds	pounds	pounds	pounds
1	Dec. 30–Jan. 26	45	91	115	110	90
2	Jan. 27–Feb. 23	82	121	101	91	99
3	Feb. 24–Mar. 23	60	97	123	69	87
4	Mar. 24–Apr. 20	52	72	107	111	86
5	Apr. 21–May 18	100	79	135	83	99
6	May 19–June 16	78	120	123	104	106
Means		70	97*	117**	95*	...

* Significant at the 5% level when compared to rotation grazing.
** Significant at the 1% level when compared to rotation grazing.

as little as strip grazing or wilt soiling. Increased forage production accounts for the decrease in acreage required as the experiment progressed.

In table 4 are presented the data on efficiency of feed utilization and the dry-matter yield per acre in the six 28-day periods. The values listed are averages of the two soiling lots. It is interesting to note that the beef produced per acre remains rather constant throughout the six periods, while declines occur in total beef production and the efficiency of conversion of dry matter to gain. This can be explained by the marked increase in forage production per acre as the season progressed.

TABLE 3. ACRES USED PER 28-DAY PERIOD [1]

Period No.	Dates	Lot 1 Rotation Grazing	Lot 2 Strip Grazing	Lot 3 Green Soiling	Lot 4 Wilt Soiling	Means
1	Dec. 30–Jan. 26	7.79	4.76	3.90	4.20	5.16
2	Jan. 27–Feb. 23	7.79	4.76	5.37	6.31	6.06
3	Feb. 24–Mar. 23	6.35	4.48	5.21	6.32	5.59
4	Mar. 24–Apr. 20	5.67	3.64	4.67	4.68	4.67*
5	Apr. 21–May 18	4.59	4.77	2.94	3.38	3.92**
6	May 19–June 16	4.25	4.39	2.37	3.13	3.53**
Means		6.07	4.47**	4.08**	4.67*	

* Signifcant at the 5% level when compared to period 2 in the case of the period means or rotation grazing in the case of the treatment means.
** Significant at the 1% level when compared to period 2 in the case of the period means or rotation grazing in the case of the treatment means.
1 Includes area used for grazing, soiling and growing for future grazing or soiling.

Decreased daily gains and the steady decline in efficiency account for the drop in total beef production during the last two periods. For the first 112 days the gains of the steers in these two lots averaged 2.12 pounds per day but dropped to 1.33 pounds during the last 56 days. It is to be expected that with warmer weather the gains on a roughage ration would decrease rather markedly. The drop in efficiency is undoubtedly due to a combination of factors since the cattle were growing older, the type and perhaps the quality of forage was changing, and the climatic conditions were changing.

TABLE 4. RELATION OF BEEF PRODUCTION TO EFFICIENCY OF FEED UTILIZATION AND DRY MATTER YIELDS

Period No.	Dates	Beef Produced		Gain per 100 Pounds of Dry Matter Intake	Dry Matter Yield per Acre Used on Experiment [1]
		Total	Per Acre		
		pounds	pounds	pounds	tons
1	Dec. 30–Jan. 26	454	112	16.0	0.36
2	Jan. 27–Feb. 23	561	96	15.8	0.39
3	Feb. 24–Mar. 23	553	96	11.6	0.45
4	Mar. 24–Apr. 20	509	109	11.0	0.57
5	Apr. 21–May 18	344	109	7.4	0.78
6	May 19–June 16	310	113	6.3	1.00

[1] Includes all acres used for soiling and growing for future use for soiling.

The lower beef production obtained from rotation grazing in this experiment must be due to a greater wastage of forage since the gains of the animals were not significantly different from those on the other treatments. The wastage might be due to trampling, lying, defecating and urinating upon the forage and to the refusal of the animals to eat the coarser parts of the plants. Soiling overcomes most of these losses and strip grazing partially does so. It should be emphasized that the results of this experiment do not necessarily mean that soiling or strip grazing should be generally used to replace rotation grazing. A number of other factors must be considered. Some of these are the cost of the forage harvesting and handling equipment, labor and the ease of fitting the program into the over-all farm operation. The data presented can be used, however, as a guide to the comparative production which can be expected by these various methods of using alfalfa as a forage crop.

Summary

The amount of beef produced in this study by rotation grazing, strip grazing, green soiling, and wilt soiling of alfalfa has been determined. No significant difference was found in the gains of steers on these four treatments. Beef production per acre, however, was significantly lower on rotation grazing than on any other treatment. Green soiling resulted in a 69 percent increase in beef production over rotation grazing, while wilt soiling and strip grazing resulted in 36 and 39 percent increases respectively.

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WOOD MOLASSES AS A FEED INGREDIENT FOR LACTATING DAIRY COWS [1]

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MOLASSES, made by acid hydrolysis of wood, has been shown to have value as a feed for cattle (Harris, 1948). Blosser *et al.* (1951) reported that when wood molasses was added to diets containing five percent less energy than Morrison's minimum standards for growing dairy cattle, growth of heifers was improved. Palatability, however, was poor, Colovos *et al.* (1949) and Jones (1949) found that for dairy heifers wood molasses contained about the same amount of metabolizable energy per gram of dry matter as does cane molasses.

The sugars of molasses from coniferous woods consist of about 80 percent hexoses and 20 percent pentoses (Hall, 1948). Respective values for sugars from hardwoods are 65 percent and 35 percent. Thus the nutritive value of molasses from these two wood sources may differ. Apparently molasses from hardwoods has been given little study to determine its nutritional value.

Three trials, in which wood molasses from mixed hardwoods was fed to lactating cows, were carried out to determine the effect of the molasses upon milk production and general health.

Experimental Procedure

The molasses used in these trials was produced from mixed hardwoods by sulfuric acid hydrolysis. The batch of molasses used in Trials I and II had a pronounced burnt odor and appearance. Following hydrolysis, this batch had been concentrated to approximately 50 percent solids by an internal burner evaporator. The batch used in Trial III had a better odor and appearance. This batch was concentrated to about 25 percent solids by an internal burner evaporator and thence to about 50 percent

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[5] The molasses used in these trials was furnished by the Tennessee Valley Authority which produced the molasses in cooperation with the U. S. Forest Service. Mr. M. L. Richards of the Department of Experimental Statistics aided with the statisical analysis and interpretation of the data. The authors express their sincere appreciation for these services.

solids by evaporation under reduced pressure. The molasses had a bitter and sour taste. The pH on 3 samples ranged from 4.11 to 4.25. The solids of these samples ranged from 44.73 to 64.45 percent. This variation was apparently due to poor sampling, the material being difficult to mix in cool weather.

Trial I, carried out in two phases, a and b, was conducted at the Central Experiment Station, Raleigh, in the early spring of 1950. Two groups, each consisting of 3 cows, were used in each part of Trial I. All cows were Ayrshires except one, a Holstein used in part b.

Trial II was conducted at the Coastal Plain Station, Willard, during the early part of 1951. Four groups of 3 Jerseys each were used in Trial II.

The ingredients of the basal concentrate mixtures for Trial Ia and Trial II were oats, corn, cottonseed meal, salt and bonemeal; whereas milo maize replaced corn in Trial Ib. For these first two trials the wood molasses was mixed into the concentrate feed, replacing either corn or milo maize, pound for pound, in amounts to provide levels of 0, 10, and 20 percent. These three levels of molasses were fed in orthogonal Latin square designs balanced for carry-over effects (Cochran, 1941), so that each cow received each level of molasses for a period of 28 days. Roughage consisted of good alfalfa hay and corn silage. Approximately three pounds of silage and one pound of hay were fed daily per 100 pounds of body weight. The amounts of roughage were held constant throughout the trials.

Trial III was conducted at Raleigh during the early part of 1951, using 3 groups (A, B, and C) of animals in a continuous trial. Each group consisted of a Jersey, a Guernsey, an Ayrshire and a Holstein cow. Molasses was fed in amounts of 0, 4 and 6 pounds per cow daily for a period of 112 days to animals in groups A, B, and C respectively. The amounts of molasses fed were too large to be mixed easily into the concentrate mixture; therefore, it was divided between the A.M. and P.M. feeding and poured over the silage. Molasses was substituted for concentrate feed in the ratio of 2 to 1, inasmuch as the molasses contained approximately 50 percent solids. Other ingredients of the rations for this trial were similar to those of Trials Ia and II.

Results and Discussion

Results from Trials I and II are summarized in tables 1, 2 and 3. The data in tables 1 and 3 do not indicate differences among the rations. The data of table 2 indicate that when 10 percent molasses

was fed with milo, the percent fat was lower than in other groups resulting in significantly less pounds of fat, and pounds of 4 percent FCM. Although the difference in percent fat is substantial, a similar

TABLE 1. AVERAGE DAILY PRODUCTION, BODY GAIN AND FEED INTAKE—TRIAL I-A

Molasses	Milk	Fat	Fat	F.C.M.	Body Gain	Grain	Hay	Silage
(%)	(lb.)	(%)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
0	37.9	3.90	1.48	37.4	—.07	13.2	10.4	30.8
10	37.9	3.85	1.46	37.0	.23	13.2	10.4	30.8
20	37.8	3.89	1.47	37.1	—.13	13.1	10.4	31.1
5% L.S.D.[1]	1.1	.25	.09	1.4	1.00	....	....	....

[1] Least significant difference.

TABLE 2. AVERAGE DAILY PRODUCTION, BODY GAIN AND FEED INTAKE—TRIAL I-B

Molasses	Milk	Fat	Fat	F.C.M.	Body Gain	Grain	Hay	Silage
(%)	(lb.)	(%)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
0	33.6	3.51	1.18	31.1	—.08	13.2	11.6	31.9
10	33.6	3.10	1.04	29.0	.13	13.2	11.6	31.7
20	33.1	3.38	1.12	30.0	—.55	13.1	11.6	31.5
5% L.S.D.[1]	1.1	.25	.09	1.4	1.00	....	....	....

[1] Least significant difference.

TABLE 3. AVERAGE DAILY PRODUCTION, BODY GAIN AND FEED INTAKE—TRIAL II

Molasses	Milk	Fat	Fat	F.C.M.	Body Gain	Grain	Hay	Silage
(%)	(lb.)	(%)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
0	21.2	5.42	1.15	25.7	.08	10.7	8.7	25.9
10	21.8	5.60	1.22	27.0	.37	10.6	8.7	26.1
20	20.9	5.60	1.17	25.9	.42	10.6	8.9	25.9
5% L.S.D.[1]	1.0	.37	.11	2.0	.61	....	....	....

[1] Least significant difference.

difference did not occur with the corn and molasses diets, and since only 6 cows were fed the milo and molasses mixtures, additional evidence is needed before concluding that this difference resulted from dietary effects.

TABLE 4. AVERAGE DAILY PRODUCTION, BODY GAIN AND FEED INTAKE—TRIAL III—ADJUSTED BY COVARIANCE FOR PRELIMINARY PERFORMANCE AND INTAKE

Molasses	Milk	Fat	Fat	F.C.M.	Body Gain	Grain [1]	Hay	Silage
(lb.)	(lb.)	(%)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
0	29.1	4.33	1.26	30.7	.52	12.6	10.0	29.5
4	33.4	3.86	1.29	32.6	.15	10.6	9.6	31.2
6	30.1	4.02	1.21	30.0	.46	7.5	10.0	29.5
5% L.S.D.[2]	2.3	.42	.15	2.1	.47	....	....	....

[1] Not including molasses.
[2] Least significant difference.

The results of Trial III, summarized in table 4, show that production was highest for those cows which received 4 pounds of the molasses daily. The low fat percentage on 4 pounds of molasses is probably attributable to the increased milk flow. Perhaps this level of molasses feeding resulted in some beneficial effect to the animals. The cows which received 6 pounds of molasses produced about the same amount of FCM as did those receiving none: however, through error, these cows were fed, proportionately, less grain than cows of the other groups. Since molasses replaced grain in this trial in the ratio of 2 to 1, grain intake should have averaged 9.6 pounds instead of 7.5 pounds for the cows receiving 6 pounds of molasses.

The results of all trials are summarized in table 5. This was done by adjusting the results of each experiment so that the average level

TABLE 5. AVERAGE DAILY PRODUCTION, BODY GAIN AND FEED INTAKE—SUMMARY OF ALL TRIALS

Molasses	Milk	Fat	Fat	F.C.M.	Body Gain	Grain [1]	Hay	Silage	FCM/ Grain
(lb)	(lb)	(%)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb/lb)
0.0	30.5	4.16	1.27	31.2	.11	12.4	10.2	29.5	2.52
1.2	30.6	4.05	1.24	30.8	.38	11.7	10.1	29.6	2.63
2.5	30.1	4.15	1.25	30.8	.07	11.1	10.2	29.5	2.77
4.0	34.8	3.68	1.28	33.1	—.26	12.4	9.8	31.2	2.67
6.0	31.5	3.80	1.20	30.5	.05	10.4	10.1	29.8	2.93
5% L.S.D.'s [2]									
(1) [3]	.6	.17	.06	.9	.51	....	....	....	....
(2) [4]	2.4	.45	.16	2.3	.69	....	....	....	....
(3) [5]	2.3	.42	.15	2.1	.47	....	....	....	....

[1] Grain plus one-half of molasses.
[2] Least significant difference.
[3] To contrast 0.0, 1.2 and 2.5 lb. of molasses with each other.
[4] To contrast either 1.2 or 2.5 lb. of molasses with either 4.0 or 6.0 lb.
[5] To contrast 0.0, 4.0 and 6.0 lb. of molasses with each other.

of the cows fed zero molasses was the same in all experiments. In order to compare grain intakes and to discern the relative value of molasses and grain, the grain intake is recorded as the gain fed plus one-half of the molasses fed. By comparing the FCM produced per pound of gain in table 5, it is evident that one pound of molasses is worth at least one-half pound of grain at all levels at which molasses was fed.

Cows readily consumed the molasses in the maximum amounts after they became accustomed to it, but they did not crave it as one would expect of cane molasses. One cow in the high molasses group did go off feed during the trial but recovered without a change in feed.

Since the molasses, following hydrolysis with sulfuric acid, was neutralized with calcium salts the question arose as to whether or not one might expect any deleterious effect due to sulfate ion. Apparently the resulting calcium sulfate was well removed since three samples averaged only .563 percent SO_4. It was not expected that this amount of sulfate would be deleterious.

Summary

Wood molasses was fed to lactating dairy cows in amounts up to six pounds per day. Wood molasses apparently is well utilized by cows, and shows promise as an ingredient of dairy cow rations. One pound of molasses was worth at least one-half pound of grain. Cows did not crave the wood molasses but palatability was not a problem. No deleterious effects were noted when fed as long as 112 days.

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PREPARATION OF THE FOETAL COMPOUND STOMACH AS AN AID IN THE TEACHING OF RUMINANT NUTRITIONAL PHYSIOLOGY [1]

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THE nutritional physiology of the ruminant compound stomach has come into a new era, and the research of the experimental animal husbandman, phsiologist, biochemist, and bacteriologist has put a new face on modern concepts of rumen physiology (Elsden and Phillipson, 1948; McCandless and Dye, 1950; Kesler *et al.*, 1951; Parrish and Fountaine, 1952).

Early studies of the topographical anatomy of the ruminant stomach (Cordier, 1894; Sisson, 1923; Lagerlof, 1928) and of the dynamic factors (Schalk and Amadon, 1928) have more recently been confirmed (Lambert, 1948; Grossman, 1949) and the dynamic factors extended and clearly demonstrated (Wise and Anderson, 1939; Hale *et al.*, 1940; Danielli *et al.*, 1945; Phillipson, 1947).

Of great practical importance to the animal nutritionist and physiologist is the means by which the ruminant derives its nutriment from the coarse fodders comprising its diet (Marston, 1939; Phillipson, 1942; Phillipson and McAnally, 1942; Barcroft *et al.*, 1944), the intermediary metabolic processes (Gray, 1948; McCandless and Dye, 1950), and the activities of the rumen microflora (Hastings, 1944). A recent review by Huffman (1953) deals with many aspects of the compound stomach.

The teaching of ruminant nutritional physiology to graduate and undergraduate students of animal husbandry, nutrition, physiology, and allied fields of study can be quite difficult and entirely confusing to the student without the aid of a three-dimensional animated prototype of the compound stomach. Furthermore the undergraduate student is likely to be more utilitarian in his attitude as his precepts are directed by the desire for practical knowledge, failing completely to appreciate the full significance of the fundamental physiologic nature of the ruminant. No amount of didactic instruction, however forcefully it may be presented, is apt to change this attitude.

Since the undergraduate students concerned have time in the normal course of their studies for the acquisition of only elementary knowledge

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of anatomy, chemistry, and physiology, the demonstration aid simplifies and replaces extensive discussion. The purpose of this paper is to describe a method of preparing a compound fetal stomach as a teaching and in ruminant nutritional physiology.

Preparation of the Stomach

The bovine foetal stomach of 175 to 195 days of prenatal development is prepared because of its desirable size. The tissues and vascular system at this stage of development are completely differentiated and well developed, and the proportionate size of the four compartments is approximately comparable to that of the adult ruminant stomach.

The stomach is dissected from the foetus along with about an inch of esophagus and an inch of duodenum, the contents are washed out thoroughly with warm tap water, and the stomach is placed in strong formalin solution (5 percent) for hardening. After several days in formalin the stomach is washed again with warm water and injected, first through the esophagus and later through the duodenum, with paraffin wax (m.p. 50–57 degrees C) preheated to a temperature of 85–90 degrees C. A large 50 ml pyrex syringe and large bore hypodermic needle are used for the injection. Immediately after the injection of the paraffin, the stomach is held under cool running tap water to hasten the setting of the wax. Manipulations at this time and application of pressure forces the paraffin evenly into all compartments and molds the stomach in the natural desired proportions. Slight hardening of the tissues by the previous formalin treatment reduces the elasticity of the stomach compartments so that their natural proportions are attained easily. Small "bull dog" haemostats are used to close off the esophagus and duodenum to prevent leakage of paraffin during the manipulation. Air pockets sometimes develop but are easily removed by puncturing with a small gauge needle and followed by injection of paraffin. Air pockets must be removed before further treatment.

After the stomach has been shaped properly and the paraffin has set, it is dried thoroughly in the absence of heat. This causes the tissue to shrink tightly around the paraffin producing a smooth surface. The dried stomach is then freed of external fat and any adhering tissue. To preserve the stomach and render it more resistant to handling, a heavy coat of banana oil-cellulose acetate in acetone is applied.[3] A second coat is applied to give the stomach rigidity and permanence of form, and consists of a mixture of 50 percent cement (colorless and

[3] A similar product can be purchased at any hobby shop. It is commonly refered to as "clear dope", manufactured by Testor Chemical Company, Rockford, Illinois.

transparent when dry) and 50 percent banana oil-cellulose acetate in acetone. Any number of coats may be applied in order to achieve the desired thickness; however, two coats will give a thickness of approxi-

Figure 1. The prepared and mounted foetal bovine compound stomach of 180 days prenatal development. The stomach is mounted in its natural position supported on 1/16th inch steel wire and balsa wood base. Clearly visible is the rumen, reticulum, omasum, and abomasum or "true stomach" which constitute the four anatomically distinct compartments of the ruminant stomach. The honeycomb structure of the reticulum, the lamella of the omasum, the several folds in the abomasum, and the relationship of the esophageal groove (E.G.) to the several compartments is also observable.

mately 1/64th inch and provides an excellent protective shell sufficient to withstand severe handling.

Any fat present in the fibroelastic tissue covering the stomach will be solubilized by the acetone vehicle and on drying the fat will be incorporated in the cellulose acetate coating in such a manner as to expose it in a permanent white cover. This effect can be observed in figure 1. While this tends to give the stomach a more normal appear-

ance, and in itself is not too objectionable, it does cover up many of the underlying structural features. To avoid this the fat is extracted with diethyl ether. After hardening the stomach in formalin it is washed with water, placed in 500 ml of ether, and allowed to stand for 18 hours. The stomach is then injected with paraffin as indicated. This procedure is to be recommended as it increases the transparency of the stomach tissue and more clearly exposes the structural features.

The prepared stomach is mounted on a balsa wood base using steel wire as illustrated in figure 1. External details may be added to a degree commensurate with the level of instruction for which the stomach is to be used. The stomach has a glossy appearance; the protective cement-cellulose acetate shell is completely transparent and rigid; the tissues are preserved indefinitely in their natural state; and unlike most prepared biological specimens, the stomach has a pleasant aroma.

Summary

A method for the preparation of the foetal compound stomach as a visual aid in ruminant nutritional physiology is described. The method consists briefly of hardening the stomach in formalin, filling it with paraffin, and applying several coats of cellulose acetate in acetone and a cement-cellulose acetate mixture. The preparation preserves the stomach tissue in its natural state for an indefinite period, lends rigidity to the stomach, and renders it resistant to frequent handling.

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SOME GROWTH RELATIONS IN RANGE CATTLE[1]

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ALTHOUGH the significance of the relationships between gains made at different periods of development by beef cattle has long been recognized, few published studies are available. Koger and Knox (1951) stressed their importance with respect to early selection, estimation of future gains from early growth, and prediction of feed lot performance of range calves. They are also of interest to the producer faced with the alternative of selling weanling calves or long yearlings.

This paper presents another study of the relation between gains made at different periods of growth and development. The environmental conditions and growth periods studied are typical of many intermountain range areas, and differ from those of previously published reports.

Source of Data

The data used in this study were obtained at the Knoll Creek Experimental Range Station of the Nevada Agricultural Experiment Station. Twenty-eight weanling steer calves were purchased in the fall of 1946, 30 in the fall of 1948, and 30 weanling heifer calves in the fall of 1950. The calves were selected on the basis of an arbitrary uniform weight each year. Since large numbers were available, and calves could have been selected with ease for any uniform weight between 300 and 450 pounds, this group might well be considered a representative sample from the range population in northeastern Nevada.

These animals were wintered on wild native hay, ranged during the summer, run on aftermath during the fall, and fed hay the second winter. This sequence of events represents the distinct environmental and management phases of growth and development to two years of age, typical of the northeastern Nevada range. Weaning weight and gains made by these 88 animals during the four periods specified provide part of the material for this study. Weaning weight and the

[1] This work is in cooperation with Bureau of Animal Industry, United States Department of Agriculture, under Western Regional Project W-1 on beef cattle breeding research.

[2] Department of Animal Husbandry. The author is indebted to Professor W. C. Rollins of the University of California for assistance in the preparation of the manuscript.

gains for the four periods are designated X_1, X_2, X_3, X_4, and X_5, respectively.

The remaining data were obtained from 67 purebred Hereford heifers selected as foundation females for a breeding experiment. Records were available from 19 heifers purchased in 1949, and 24 each purchased in 1950 and 1951. These animals represent 19 half-sib groups and were selected as a random sample of two lines of breeding prominent in Nevada. They were fed and managed under conditions similar to the grades. Data were obtained for the same periods.

Results and Discussion

During the winter feeding period the grade cattle were divided into two groups; one group was fed hay cut early in the summer and the

TABLE 1. MEAN VALUES OF GAINS FOR FIVE GROWTH PERIODS, AND GROSS CORRELATIONS BETWEEN PERIODS

Item	Mean Gain	Correlation with			
		X_2	X_3	X_4	X_5
X_1	428.0	0.06	0.08	—.06	0.15
X_2	89.5	....	—.20*	0.05	0.24**
X_3	207.1	....	....	—.36**	0.04
X_4	—13.2	....	....	....	—.19*
X_5	89.2	....	....	....	....

* Significant at the 5% level.
** Significant at the 1% level.

other, hay cut later. There was some variation in hay quality in different years. The data were analyzed on an intra-year, intra-feeding group basis to eliminate the effects of year, hay quality, and sex. Mean values for the five variables and gross correlations are shown in table 1.

Directly comparable correlations were not available in the literature. Koger and Knox (1951) reviewed the studies of Hultz (1927), Lush (1932), Woodward *et al.*, (1942), Stanley and McCall (1945) and Knox and Koger (1946) which indicate that growth prior to feeding age is positively associated with feed lot gain. They also cited the report of Black *et al.* (1938), which indicated that height at withers and body length are negatively correlated with feed lot gain, but that width was positively associated with gain.

Koger and Knox (1951) studied weight gains made by grade Hereford cattle on the semi-desert range of the New Mexico College of

A & M A. They found the growth rate of steers on the range to be positively correlated with feed lot gain, and in general, that growth on the range at different periods was positively correlated. They concluded that when the environment is constant for different animals, there is a positive relation between gains made at different periods. However, this relation can be obscured or reversed by changing the environmental conditions considerably.

None of the correlations involving weaning weight are significant, although the correlation between weaning weight and gain during the second winter approaches significance. Koger and Knox (1951) found a small but significant negative correlation between weaning weight and long yearling gain—an age figure comparable to the sum of periods X_2 and X_3 of this study. Low or non-significant correlations with weaning weight are to be expected, since weaning weight is largely a function of the dam's maternal ability (Knapp and Clark, 1950). From a production viewpoint, these results favor the practice of selling the heaviest calves as weanlings, and lighter ones as long yearlings.

The correlation between the two winter feeding periods is positive and significant. This may indicate the existence of a group of genes which influence adaptability to winter feeding conditions, and which are at least partially independent.

Correlations between succeeding periods—first winter and summer range, summer range and aftermath, and aftermath and second winter—are significant and negative. Koger and Knox (1951) concluded "A negative relationship would be expected when environmental variations are experienced during one period and later removed, allowing a compensation for over or under growth during the first period." Errors in weighing such as shrink and fill also tend to contribute to negative correlations between successive periods. Nutritional and other environmental factors differ widely among the growth periods considered in this study. This is reflected in the mean gains for the different periods. These correlations might be interpreted as indicating that, under the conditions of this study, there is an inverse relation between adaptability to winter feeding conditions and summer and fall range and grazing. These findings are in agreement with, and tend to confirm, those of Koger and Knox.

Knapp and Clark (1947) studied the phenotypic, genetic and environmental correlations between gains made during each of three

84-day periods of a 252-day feeding test of steers started as weanlings. Environmental influences were reduced to minimum. They concluded that heredity plays a most important part in determining the gains of calves in the feed lot.

The utility of knowledge of these correlations for the periods of this study is obvious. Data from the purebreds were amenable to the analysis developed by Hazel, Baker and Reinmiller (1943) and adapted to beef cattle data by Knapp and Clark (1947, 1951). Details of the technique are clearly described in these papers and need not be repeated.

The four significant gross correlations based on the combined data were determined from the purebred data only and are shown in the first line of table 2. A correlation of 0.25 would be required for

TABLE 2. GROSS, GENETIC, ENVIRONMENTAL AND PHENOTYPIC CORRELATIONS AMONG PUREBRED ANIMALS

	Period			
Correlation	X_2X_4	X_2X_5	X_3X_4	X_1X_5
Gross	—.22	0.27	—.39	—.21
Genetic	—.16	0.35	0.12	—.65
Environmental	—1.00	—1.00	—.50	0.12
Phenotypic	—.23	0.25	—.41	—.19

significance at the 5% level. Two are significant, and two closely approach significance at the 5% level. The correlations based only on the purebred data are in close agreement with those based on the pooled data. Genetic, environmental and phenotypic correlations for the four periods are shown in table 2. The phenotypic correlations were obtained from addition of the genetic and environmental variances and covariances.

Heritability of gain was estimated for each of the five periods as follows: X_1, 1.00; X_2, 0.99; X_3, 0.15; X_4, 0.15; X_5, 0.83. Knapp and Nordskog (1946), and Knapp and Clark (1947, 1950), estimated heritability of weaning weight at 12, 30 and 28 percent, depending upon the method and data. These animals were born on 4 different ranches, each with 2 to 6 sire groups. Pre-purchase environmental conditions, which affect all calves from the same ranch alike but which vary among ranches, appear in these heritability estimates. It did not appear feasible to attempt adjustment of weaning weights or gains for these influences. This bias, in addition to sampling error, may

account for the large heritability estimate for weaning weight. Knapp and Clark's (1950) revised estimate of heritability of gain on feed is 65 percent. Previous estimates ranged from 65 to 99 percent. Gain during the two winter feeding periods, X_2 and X_5, is similar, but not exactly comparable. Heritability estimates for these periods are also similar.

There is a small negative genetic correlation between gains made during the first winter and on summer range. The environmental correlation is negative and estimated at unity. This would indicate the greater importance of environmental influences and that there is a small negative relation between genes conditioning adaptability to winter feeding and ranging ability.

The fairly large positive genetic correlation between gains for the two winter feeding periods supports the hypothesis that adaptability to different winter feeding periods is conditioned by many of the same genes. The importance of environment is indicated by the large negative enironmental correlation.

Environment is of greatest importance in determining the correlation between gains on the range and on aftermath. The genetic correlation is positive however, indicating a common genetic influence on adaptability to ranging and grazing conditions.

There is a large negative genetic correlation between gains on aftermath and during the second winter. This further suggests an inverse genetic relation between adaptability to winter feeding conditions and grazing conditions. Although this inverse relation has been observed in these data, there is no *a priori* reason for assuming that it will prevail in all populations. The observation of Koger and Knox (1951) of a positive correlation between gains on the range and in the feed lot indicates that it does not prevail in all populations. The low heritability estimates for X_3 and X_4, considered with the non-significant gross correlations of X_2X_4 and X_3X_5 and the high heritability estimates for X_2 and X_5 considered with the significant correlation X_2X_5 might indicate absence of genetic incompatability between gains made on the range and during winter feeding, but rather a lack of environmental control of gains on the range. These cattle have been selected for several generations largely on the basis of adaptability to range conditions. The genetic correlation might well be due to drift.

The relatively large environmental correlations found in this population, as compared with those observed by Knapp and Clark (1947), are probably due to the drastic changes in environment between the

periods of this study, in contrast to the minimized environmental variation of the former.

These results indicate that environmental influences are of great importance, but that heredity plays a significant role in the relation between gains made at different periods.

Summary

Weight gains for five periods of growth and development were obtained on 88 grade and 67 purebred Herefords at the University of Nevada Experimental Range Station in northeastern Elko County. The 10 gross correlations between the five periods were calculated. None of the correlations involving weaning weight were significant. A positive correlation was observed between gains made during the two winter feeding periods. Correlations between succeeding periods were negative and significant. It is concluded that under the variable environmental conditions of this study there is an inverse relation between adaptability to winter feeding and summer grazing on the range.

Genetic, environmental and phenotypic correlations were estimated from the purebred data for the four correlations found significant in the total data. A large, positive genetic correlation was found between gains made during the two winter feeding periods, indicating a common genetic influence on adaptability to winter feeding. In general, environmental correlations were larger than genetic correlations. It is concluded that environmental influences exert the greatest effect on the relation between gains at different periods, but that heredity is also effective.

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RELATIONSHIPS OF MEASUREMENTS OF LIVE ANIMALS TO WEIGHTS OF GROUPED SIGNIFICANT WHOLESALE CUTS AND DRESSING PERCENT OF BEEF STEERS [1]

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A STUDY of the possibility of using measurements taken on live beef steers for the purpose of predicting the actual weights of wholesale carcass cuts was presented by White and Green (1952). It was found that the weights of the major cuts were quite highly correlated with sets of measurements, and that linear measurements were of value for estimating the weight of cuts when used alone or as adjuncts to live weight. The relationships of the findings of that study to livestock judging were discussed. This present study is a continuation and extension of the first one and the primary objective remains the same; namely an attempt to find new or perhaps to improve the present methods of selecting breeding stock.

Materials and Methods

Data gathered on the same fifty steers described previously (White and Green, 1952) are the basis for the present study. The statistical treatment is similar to that previously used; additional methods are based on those given by Snedecor (1948). As a number of the measurements used in this study are the same as were used before, only hitherto undescribed measurements will be defined. Lettering and numbering systems will be given as continuations of those already initiated.

The thickness of hide (y) was secured by drawing up a fold of skin over the 12th rib about ¼ to ⅓ of the way down from the dorsal mid-line and measuring the double thickness of skin to the nearest 0.01 cm. by means of a small caliper.

Projected distances measured to the nearest 0.01 foot by use of a large metal caliper were: (z) Heart girth to shoulder point, the horizontal distance from a location lying in the vertical plane of the heart girth to the skin covering the anterior surface of the lateral

[1] Scientific Article No. A-435 Contribution No. 2480 of the Maryland Agricultural Experiment Station (Department of Animal Husbandry). The work on which this publication is based was not supported by regional funds but was carried on by Maryland personnel associated with the regional project and parallels the work under the S-10 project.

[2] The author is indebted to Messrs. W. J. Corbett, G. L. Jessup, Jr. and F. E. White who assisted in collecting and analyzing the data.

tuberosity of the humerus. (A) Height from the floor to the top of the withers. (B) Width of paunch, the transverse distance at the widest part of the paunch. (C) Pin to shoulder point. (D) Hook, the skin covering the anterior surface of the tuber coxae, to the shoulder point.

Measurements made to the nearest 0.01 foot by means of a tightly drawn steel tape (taken along the dorsal or cranial median line unless otherwise stated) were as follows: (E) Width between the "temples", the transverse distance between the approximate centers of the supra-orbital depressions. (F) Width of muzzle, a horizontal, straight-line distance at the widest point immediately behind the nostrils. (G) Highest point of the poll to the tip of the muzzle. (H) "Temple" to muzzle, from a line joining the approximate centers of the supraorbital depressions to the tip of the muzzle. (I) Base of the poll (atlas joint) to the withers. (J) Posterior aspect of the 13th rib to the hook, a horizontal measurement taken not along the mid-line but at the level of the hook. (K) Pin to hook, a medial measurement terminated at transverse lines joining the hooks anteriorly and pins posteriorly.

Results and Discussion

The most frequent cominations of wholesale cuts used for reporting the yield of beef carcasses are the weight of the whole carcass and/or the weights of the front and hind quarters. This is a contrast with reports on pork carcasses where yields are frequently given in terms of the four (ham, lion, picnic shoulder, and butt) or five (the four plus bacon) primal cuts. In this study, two groupings were made of what might be considered preferred or primal cuts [(I) the round, trimmed loin, and rib; and (II) the three of I plus the cross-cut] for the purpose of finding the measurements which would correlate most highly with the weights of the preferred cut groupings.[3]

The means, standard deviations, and coefficients of variation for preferred cut groups I and II as well as other items to be used later are given in table 1. The coefficients of variation follow the same trends as those given previously by White and Green (1952). Larger values are associated with the shorter distances measured along the dorsal

[3] Mr. O. G. Hankins and his associates of the Meat Section, Division of Animal Husbandry, B.A.I., U.S.D.A. use the term preferred cuts to signify the round, loin end, short loin, and prime ribs (see Report of the Chief of the Bureau of Animal Industry, Agricultural Research Administration, 1949, p. 9). The loin end and short loin were combined in this study because of the closeness of relationships of measurements to the two segments of the loin and the whole, trimmed, loin found by White and Green (1952). The cross-cut is comprised of the regular chuck, brisket, and foreshank.

mid-line. Longer distances along the vertebral column have coefficients similar in magnitude to those measurements involving the long bones. Table 2 presents most of the zero order correlations of measurements used in connection with studies of preferred cuts I and II. Correlations

TABLE 1. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION OF MEASUREMENTS TAKEN ON LIVE STEERS AND PREFERRED CUT GROUPINGS I AND II (N=50)

Measurement or Cut	Item No.	Mean	Standard Deviation	Coefficient of Variation	Units of Measurement
				percent	
Pin to withers	(34)	4.21	0.21	5.1	ft.
Width of paunch	(35)	1.99	0.12	6.2	ft.
Pin to shoulder point	(36)	4.85	0.21	4.3	ft.
Hook to shoulder point	(37)	3.35	0.19	5.6	ft.
Poll to pins	(38)	5.91	0.33	5.5	ft.
Withers to hooks	(39)	2.56	0.19	7.3	ft.
Depth of chest/ withers to hooks	(40)	0.97	0.10	10.0	...
Poll to withers	(41)	1.70	0.19	10.9	ft.
Width between "temples"	(42)	0.64	0.05	7.4	ft.
Width of muzzle	(43)	0.46	0.05	9.9	ft.
Poll to muzzle	(44)	1.63	0.08	4.6	ft.
"Temple" to muzzle	(45)	1.22	0.10	7.9	ft.
13th rib to hook	(46)	0.63	0.10	15.8	ft.
Pin to hook	(47)	1.70	0.13	7.9	ft.
Height at withers	(48)	4.13	0.21	5.1	ft.
Heart girth to shoulder point	(49)	1.12	0.11	9.6	ft.
Thickness of hide	(50)	1.21	0.24	19.6	cm.
Hot carcass weight	(51)	651.50	97.06	14.9	lb.
Dressing percent	(54)	58.21	2.27	3.9	[1]
Preferred cuts I	(I)	313.66	45.24	14.4	lb.
Preferred cuts II	(II)	537.17	77.74	14.5	lb.

[1] Dressing percent calculated as warm weight of the carcass/live weight.

not given in table 2 were presented in table 2 of the previous report (White and Green, 1952).

Zero order and first order partial correlations of preferred cuts I and II with various measurements are shown in table 3. The first order partial correlations indicate that in most cases the magnitude of the simple correlations is due primarily to the mutual associations of preferred cuts I or II and the measurements with weight. It should be noted that, among the partial correlations, only width of shoulders and depth of twist are significantly correlated with preferred cuts

TABLE 2. ZERO ORDER CORRELATIONS OF MEASUREMENTS STUDIED IN CONNECTION WITH PREFERRED CUT GROUPINGS I AND II (N=50)[a, b]

Measurement or Cut	Item No.	Item No. (17)	(20)	(21)	(23)	(24)	(25)	(28)	(29)	(31)	(34)	(35)	(36)	(37)	(38)	(39)	(40)
Live weight	(1)										.58	.41	.70	.38	.61	.11	.25
Slaughter grade	(2)										−.09	.34	−.02	−.20	.04	−.19	.28
Width of loin	(4)	.60	.65	.62	.73	.36	.62	.64	.70	.53	.48	.55	.58	.35	.51	.20	.07
Width of hooks	(7)	.51	.71	.71	.77	.50	.92				.69	.44	.67	.43	.70	.33	.06
Mid-rump to rear flank	(12)	.48	.67	.74	.76	.44	.66				.65	.46	.63	.38	.64	.27	.08
Circumference of paunch	(13)	.54	.50	.52	.60	.21	.48	.32	.39	.43	.23	.62	.32	.20	.23	.11	.04
Circumference of rear flank	(14)	.61	.69	.73	.87	.42	.68	.68	.72	.63	.55	.59	.60	.40	.64	.12	.19
Width of crops	(17)							.29	.54	.39	.14	.38	.28	.01	.20	−.17	.26
Withers to fore flank	(20)							.62	.62	.50	.45	.43	.55	.28	.53	.06	.26
Withers to knee	(21)							.78	.61	.65	.68	.33	.72	.49	.66	.37	−.05
Circumference of heart girth	(23)							.62	.74	.62	.54	.48	.67	.40	.65	.02	.34
Depth of chest	(24)							.46	.30	.55	.51	.16	.57	.39	.53	.02	.63
Width of shoulders	(25)							.54	.72	.69	.38	.35	.40	.12	.38	.12	.08
Mid-rump to point of hock	(28)										.76	.34	.68	.39	.70	.41	−.01
Width of thighs	(29)										.50	.38	.53	.25	.53	.21	.02
Depth of twist	(31)										.58	.52	.56	.48	.58	.20	.20
Pin to withers	(34)											.20	.75	.60	.85	.58	−.11
Width of paunch	(35)												.37	.34	.35	−.07	.16
Pin to shoulder point	(36)													.77	.75	.44	.03
Hook to shoulder point	(37)														.63	.42	−.07
Poll to pins (41+34)	(38)															.23	.19
Withers to hook (22+16+3)	(39)																−.75
Depth of chest/withers to hook	(40)																1.00

[a] For correlations not given here see White and Green 1952).
[b] Correlations of 0.28 are significant at the 5 percent level and 0.36 at the 1 percent level.

I, and that only those two measurements and width of hooks are significantly correlated with preferred cuts II. Some of the other relationships will be discussed later.

TABLE 3. ZERO ORDER AND FIRST ORDER PARTIAL CORRELATIONS OF COMBINED WEIGHTS OF PREFERRED CUTS (I) ROUND, TRIMMED LOIN, AND RIB AND (II) ROUND, TRIMMED LOIN, RIB AND CROSS CUT WITH VARIOUS LINEAR MEASUREMENTS (N=50)

Measurement	Item No.	Zero Order Correlations		First Order Partial Correlations	
		$r(\ )I$	$r(\ )II$	$r(\ )I \cdot (1)$	$r(\ )II \cdot (1)$
Live weight	(1)	0.95**	0.96**	.....	.....
Slaughter grade	(2)	0.30*	0.29*	0.132	0.088
Withers to fore flank	(20)	0.68**	0.69**	0.006	0.010
Withers to knee	(21)	0.72**	0.72**	0.029	—0.005
Mid-rump to point of hock	(28)	0.70**	0.71**	0.189	0.206
Mid-rump to rear flank	(12)	0.75**	0.74**	0.200	0.135
Pin to withers	(34)	0.54**	0.55**	—0.015	0.003
Circumference of heart girth	(23)	0.88**	0.88**	0.004	—0.026
Circumference of paunch	(13)	0.52**	0.51**	0.151	0.086
Circumference of rear flank	(14)	0.79**	0.78**	0.235	0.166
Width of shoulders	(25)	0.81**	0.81**	0.448**	0.429**
Width of crops	(17)	0.68**	0.66**	0.161	0.068
Width of paunch	(35)	0.43**	0.41**	0.161	0.088
Width of loin	(4)	0.74**	0.75**	0.101	0.147
Width of hooks	(7)	0.80**	0.81**	0.258	0.312*
Width of thighs	(29)	0.75**	0.78**	0.060	0.141
Depth of twist	(31)	0.66**	0.66**	0.317*	0.333*
Pin to shoulder point	(36)	0.63**	0.63**	—0.121	—0.159
Hook to shoulder point	(37)	0.35*	0.35*	—0.015	—0.028
Poll to pins	(38)	0.56**	0.57**	—0.067	—0.039
Withers to hooks	(39)	0.15	0.14	0.125	0.092
Depth of chest	(26)	0.50**	0.52**	—0.093	—0.034
Depth of chest/ withers to hook	(40)	0.20	0.21	—0.122	—0.074
Preferred cuts I	....	....	0.99**	.....	0.891**

* Statistically significant at the 5 percent level.
** Statistically significant at the 1 percent level.

As one of the primary objectives of this work is to find, if possible, combinations of measurements which will afford means of estimating the weights of cuts which might give promise for future studies on aids for the selection of breeding animals, mutiple correlations were computed involving preferred cuts I and II with measurements which were significantly correlated in the partial correlations, plus slaughter grade. Lines *a* and *c* of table 4 indicate that for the kind of steers

TABLE 4. STANDARD PARTIAL REGRESSION COEFFICIENTS (BETAS) AND MULTIPLE CORRELATION COEFFICIENTS (R) FOR VARIOUS COMBINATIONS OF MEASUREMENTS PERTAINING TO GROUPED PREFERRED CUTS I AND II [a] (N=50)

Reference Line	Width of Loin	Mid Rump to Rear Flank	Width of Thighs	Width of Shoulders	Circumference of Heart Girth	Depth of Twist	Width of Hooks	Slaughter Grade	Live Weight	Preferred Cut Groupings			
										I		II	
										R **	R^2	R **	R^2
	(4)	(12)	(29)	(25)	(23)	(31)	(7)	(2)	(1)				
a				0.181		0.061		0.026	0.776	0.960	0.921		
b				0.662		0.187		0.073		0.826	0.682		
c				0.192		0.070	−0.053	0.013	0.806			0.966	0.933
d				0.343		0.163	0.369	0.045				0.834	0.696
e	0.124	0.118	0.043	0.288	0.453					0.919	0.845		
f		0.130	0.136	0.300	0.458					0.919	0.844		
g			0.143	0.326	0.532					0.915	0.837		
h				0.350	0.619					0.910	0.828		

[a] I represents the combined weights of the round, trimmed loin, and rib and II those three cuts plus the cross-cut.
** All correlations are statistically significant at the 1 percent level.

used in this study, little is to be gained from the use of the indicated linear measurements if live weight is known [$r_{(1)(I)}$=0.948 and $r_{(1)(II)}$=0.956]. Slaughter grade and depth of twist were found to be of little additional value as members of the groups of measurements of lines *a* to *d*. The magnitude of $R_{I\cdot(25)(1)}$ was 0.959. Because this latter R is essentially the same as $r_{(1)(I)}$, live weight alone seems to be the simplest predicator for the weight of the preferred cuts I when the live weight varies in a manner similar to that encountered in this study. The same, apparently, is true for preferred cuts II. Lines *b* and *d* of table 4 indicate that the weights of preferred cuts I and II can be estimated with reasonable accuracy if live weight is not known; however, as preferred cuts I and II are correlated with width of shoulders to an extent of 0.81, table 3, there is seemingly little use of including the other measurements of lines *b* and *d*.

The zero order correlations of the various measurements with preferred cuts I and II were quite similar and for that reason further exploration of measurements for possibly predictive purposes was confined to group I. As shown on lines *e* to *h* of table 4, the Rs are essentially equal and the use of only the two measurements indicated on line *h* appears to be sufficient. The addition of circumference of heart girth to width of shoulders gives more information than any or all of the measurements utilized in lines *b* and *d* of table 4. This is not surprising as circumference of heart girth is correlated with body weight to an extent of 0.93, higher than any other single measurement. If prediction of the weights of preferred cuts I or II is desired, in the absence of body weight, width of shoulders and circumference of heart girth are suggested. (For additional information on the value of heart girth see table 3 of White and Green, 1952).

One commonly used method for predicting the weight of the carcass of an animal is to estimate the dressing percent. This item is usually not a part of direct scoring systems for breeding stock, but it has a value if the dressing percent of progeny is estimated and this in turn entered as a credit to the breeding animal. Forty different measurements were correlated with dressing percent and the results are tabulated in table 5. (Correlations between the measurements and the percent offal would be the same numerical size but of opposite sign). A good share of the correlations are essentially zero in magnitude and width of shoulders is the only measurement to be significantly correlated with dressing percent. The correlation between live weight and dressing percent is quite low.

TABLE 5. ZERO ORDER CORRELATIONS BETWEEN DRESSING PERCENT AND MEASUREMENTS OF LIVE STEERS[a] (N=50)

Measurement	Item No.	r
Live weight	(1)	0.08
Slaughter grade	(2)	0.20
Width between "temples"	(42)	0.07
Width of muzzle	(43)	0.13
Poll to muzzle	(44)	0.06
"Temple" to muzzle	(45)	0.16
Poll to withers	(41)	—0.06
Withers to fore flank	(20)	0.12
Withers to knee	(21)	0.03
Withers to 5/6 rib	(22)	0.01
5/6 to 12/13 rib	(16)	0.06
12/13 rib to hook	(3)	0.01
12/13 rib to mid-rump	(10)	0.04
13 rib to hook	(46)	—0.06
Pin to hook	(47)	—0.01
Pin to mid-rump	(27)	—0.14
Pin to withers	(34)	0.03
Circumference of heart girth	(23)	0.11
Circumference of paunch	(13)	0.17
Circumference of rear flank	(14)	0.19
Mid-rump to point of hock	(28)	0.13
Mid-rump to rear flank	(12)	0.10
Height at withers	(48)	0.01
Depth of chest	(24)	—0.02
Width of shoulders	(25)	0.30*
Width of crops	(17)	0.16
Width of paunch	(35)	0.18
Width of loin	(4)	0.16
Width of hooks	(7)	0.25
Width of thighs	(29)	0.10
Width of pins	(30)	—0.14
Depth of twist	(31)	0.26
Pin to shoulder point	(36)	—0.09
Hook to shoulder point	(37)	—0.01
Stifle to "bulge"	(32)	—0.04
Heart girth to shoulder point	(49)	0.08
Depth of rib	(18)	0.15
Depth of loin	(5)	—0.08
Thickness of hide	(50)	0.05
Depth of chest/withers to hook	(40)	—0.04

[a] Dressing percent was based on the warm weight of the carcass.
* Indicates statistical significance at the 5 percent level.

Partial correlations between various measurements and dressing percent after the effects due to variations in live weight had been removed

were essentially the same size as the original zero order correlations and effected no changes in levels of significance.

One multiple correlation was calculated involving dressing percent with width of shoulders, width of hooks, depth of twist, slaughter grade, circumference of rear flank, and live weight. A non-significant R of 0.429 was found. Apparently dressing percent could not be predicted with high accuracy by the measurements used; a better estimate could be secured by calculating the weights of the various individual wholesale cuts by use of measurements and summing the weights.

A number of interesting implications seem to be evolving from these studies. The width of shoulders has been of importance in predicting the weight of the cross-cut, preferred cuts I and II, and dressing percent. Shoulder-width correlated reasonably well with depth of twist (0.69), live weight (0.76), heart girth (0.75), width of crops (0.78), width of thighs (0.72), and quite highly with width of hooks (0.92). Excepting live weight and heart girth from the list, the measurements with which width of shoulders is best correlated seem to be direct or indirect measures of muscle tissue, especially in the steers studied. There are some reasons to believe that width of shoulders is determined quite largely by the amount of muscle, as a cross section through that area includes relatively few other parts that would probably contribute much to variations in width of the shoulders. Variations in thickness of hide, long bones and ribs could contribute some, but most likely little, to the differences in width of the shoulders. The ribs in that area show little arch. Differences in the width of the vertebrae and sternum could affect the width but fat and muscle appear to be the major tissues or parts which might tend to widen the area. As the steers were reasonably uniform in finish and not overly fat, variations in the width of shoulders may have been due primarily to differences in muscling. Depth of twist was to a large extent a measure of muscle as it was taken from the lower border of the anus to the crotch, and the steers had only reasonable amounts of crotch fat. Observations of the carcasses and palpation of the crotch indicated that little fat was included in the measurement. The partial correlation of width of shoulders and depth of twist after removing the effects due to variation in body weight was 0.44, indicating that weight of animal accounted for only part of the closeness of association between the two structures.

Width of crops was slightly difficult to measure with the same degree of accuracy as most of the other measurements. The main structural parts in common between the width of shoulders and crops were the vertebrae which could have a direct effect on the width of crops and some effect in the width of shoulders by determining the distance between opposing ribs, at least in the dorsal area. The muscles of the two structures differ but some of the size of the correlation of the two width measurements may well be due to general quantitative muscling. Width through the thighs was primarily a measure of muscle as was the depth of twist. As width of shoulders has been found to be of importance (a) in estimating the yield of cuts, and (b) to be associated with other proposed measures of muscle, the question could be raised as to the validity of the practice of sacrificing (at times) absolute width of shoulders to get desired compactness of shoulder—where compactness is frequently judged by the relative widths of the shoulder and the heart girth region. Could not the width in this latter region be allowed to be determined by biological requirements, whatever they may be, without extra effort being made to widen this area to bring it to the width of the shoulder or more important perhaps limiting shoulder width to width through the region of the heart girth?

Width of hooks was omitted from the above discussion as it seemed to deserve separate mention. It was found to be of importance in the prediction of the weight of the round even though it was not a part of that wholesale cut. Width of hooks was also shown to be of importance in estimating the weight of the trimmed loin in table 5 of White and Green (1952). That study showed that R values were essentially the same whether width of lion was used or not (lines *a*, *c* and *b*, *e*) indicating that when width of hooks was used, little if anything was to be gained by adding width of loin. The same situation was true in connection with the sirloin butt (table 7 of previous publication). Width of hooks and width of shoulders were highly correlated and the first order partial correlation after variations due to live weight had been removed was 0.79. The shoulder and hook areas differ embryologically and structurally; their association may be due to general "width factors" but perhaps might be due to each being a direct or indirect measure of the amount of muscling in the body especially if one were to postulate a cause and effect relationship between the width of hooks and the amount of muscle attached to or

passing over the area. As with the width of shoulders, the practice of attempting to get narrowness through the region of the hooks in order to have uniformity of lines along the back seems to be open to question if wider hooks may mean more muscle.

According to judging standards, width of body in the dorsal area is desired and wide bodies are secured in the animals of excellence. Uniformity of width is also desired but at times uniformity seems to be secured at the sacrifice of width. Other times, especially in show animals, uniformity is secured less by basic structural uniformity (as it literally might appear on the surface) than by a covering of fat applied under the skin which helps to fill various depressions. If type for production may be divorced from type for show purposes, perhaps then more emphasis could be placed on having animals large where it really counts as far as furnishing meat is concerned and less attention be paid to uniformity of lines and other probably esthetic values.

Depth of chest has been found to be correlated to a rather low degree with various measurements which means, of course, that being more or less independent of other measurements it needs to be evaluated more specifically for its own merits. Depth of chest was not found to be of much predictive value for estimating; (a) live weight, (b) dimensions of near-by parts, as it was correlated with the withers to fore flank to an extent of only 0.48 and in a first order partial with circumference of heart girth, $r_{(24)(23)\cdot(1)}$, of only 0.17, (c) preferred cuts I or II, or (d) dressing percent. As, commercially, rib cuts are usually removed a definite distance from the vertebrae, deeper chests should, under those circumstances, contribute to additional weight of plate which is cheaper meat containing a goodly proportion of bone. Study seems to be indicated on the real value of deeper chests. If depth of chest is really associated with "constitution" or "vital capacity" then seeking deep chests could be justified. Not much of definite value was found for deeper chests in this study.

Somewhat associated with the problem of depth of chest is that of length and depth of body. Distances along the dorsal mid-line were found to be of little assistance in predicting the weights of individual wholesale cuts; and measurements such as pin-to (a) poll, (b) withers or (c) shoulder point or hooks-to (a) withers or (b) shoulder point were of little value in connection with preferred cuts I or II, table 3. If shorter bodies in terms of actual lengths, or as indicated by the

ratio of depth of chest/withers to hooks, are really associated with higher yields of cuts of meats, it was not shown in this study. Although some of the correlations may indicate that longer bodies were perhaps associated with higher yields of cuts, the sizes of the correlations were so low that they were of no value in this connection. More study seems to be needed of the real value of shortness and depth of body, not only in connection with their supposed relationships with vital capacity but also with the yield of meat and dressing percent as table 5 indicates.

A number of questions appear to have been raised as one product of these studies. It is true that the data are not based on a large number of animals, and that the steers represent but one segment of the cattle that reach the market. It is reasonably obvious that if all kinds of cattle had been used, the results would probably differ from those secured and might perhaps fit more closely to some of the present-day ideas and teachings associated with livestock judging. In this connection, however, the question might be asked as to the amount and kind of actual data which have been analyzed and used to form a basis for a number of our present-day standards and teachings. There is evident need for studies on many phases of ideas and teachings now used in connection with judging animals so that as many of these teachings as possible can be confirmed on a factual basis or be separated into a part of the lore of animal husbandry.

The problem of the evaluation of present-day teachings can be divided into two categories, that of studying the whole range of degrees of goodness of animals and that of inter-relationships among characteristics of animals of a similar type—segments of the range. Both approaches are important but the latter may be more so as when animals are judged or evaluated, the problem is usually one of selecting from among a more or less uniform group rather than from a group containing the extremes. Comparison of extremes may be useful for drawing certain conclusions, but, unfortunately, it may lose value rapidly under frequent situations when animals are being judged.

Summary and Conclusions

Correlations were made between linear measurements taken on live animals, live weight and slaughter grade and grouped wholesale cuts of beef and dressing percent. The groupings of preferred cuts were: (I) the round, trimmed loin, and rib and (II) the three of (I) plus

the cross-cut. Live weight was found to be the single measurement most closely associated with the weights of groups I or II. Width of shoulders and hooks and depth of twist were more highly correlated with I and/or II than other linear measurements. Width of shoulders was the only linear measurement significantly correlated with dressing percent. The results of this and a former study were discussed in relation to judging practices.

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A PORTABLE SCALE FOR CATTLE RESEARCH[1]

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University of Maine

ALMOST all cattle research involves weighing of the animals. A portable scale, which can be transported easily and made ready for use with a minimum of effort, will increase the scope of the research which can be undertaken and the accuracy of the data. Work can be carried out on cooperating farms which are not equipped with scales.

Cattle research at the Agricultural Experiment Station at the University of Maine is conducted in several distant areas. It was, therefore, decided to make the stationary scale portable.

The scale at hand was a Howe scale, with a 52 inch by 76½ inch platform and a capacity of 3,500 pounds. The frame, as well as the platform of this scale was constructed of wood. Because of the wooden construction, a heavy trailer frame of 6-inch channel iron was built (figure 1) and the scale supports welded to this. Some of the wooden structure of the scale was cutaway (figure 2) and the scale frame bolted directly to the trailer frame. The result was a very rugged and solid unit.

The beam was lowered so it would be in easy reach of the operator. The frame was further reinforced with corner brackets (figure 3). The platform in front of the scale was covered with 2-inch planking (figure 3). This platform extends 38 inches beyond the scale platform and is 69 inches wide. This provides ample space to allow the animal an exit from the side of the scale. This type of exit makes it possible to use the scale without unhooking it from the truck. The weighing crate (figure 4) was constructed of heavy oak uprights fastened directly to the scale platform with special heavy duty, custom-built, angle irons (figure 5). This allows the crate to be weighed and it, therefore, does not matter whether the animal rubs against the sides. This type of construction makes the sides rugged enough to eliminate cross-bracing at the top of the crate. This lets the operator walk through the crate with unlimited headroom.

The gross weight of the scale is 3,500 pounds, making it necessary to equip the trailer with electric brakes. A heavy-duty truck-type ball and socket trailer hitch was used.

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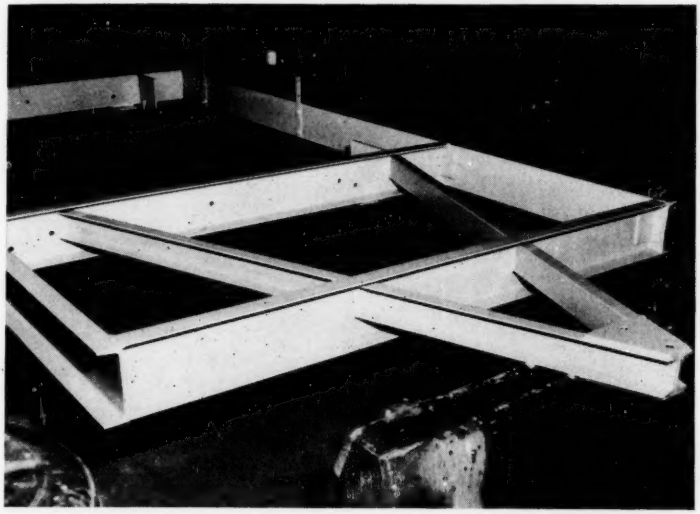

Figure 1. Trailer frame of 6 inch channel iron is electrically welded. Detail of hitch (made of 3 inch channel iron) and scale supports are shown.

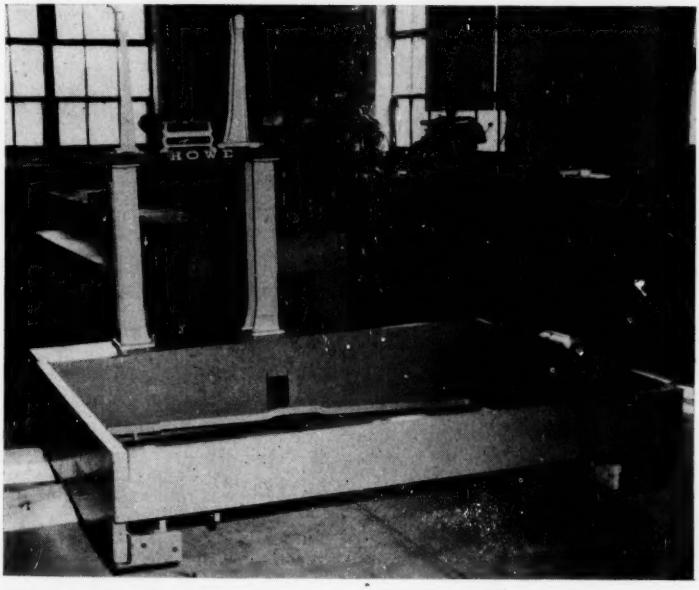

Figure 2. The "Howe" scale has a 4' x 6' platform. The wooden frame has been cut and made ready to be fastened in the trailer frame.

Since it is essential that all movement of the knife edges of the scale during transit be eliminated, four, half-inch turn buckles were used, one on each corner of the weighing crate (figure 6). These are adjusted to about 3,000–3,500 pounds of pressure as indicated on the weigh beam, and then locked into position with a locknut. This prevents side sway as well as up and down movement.

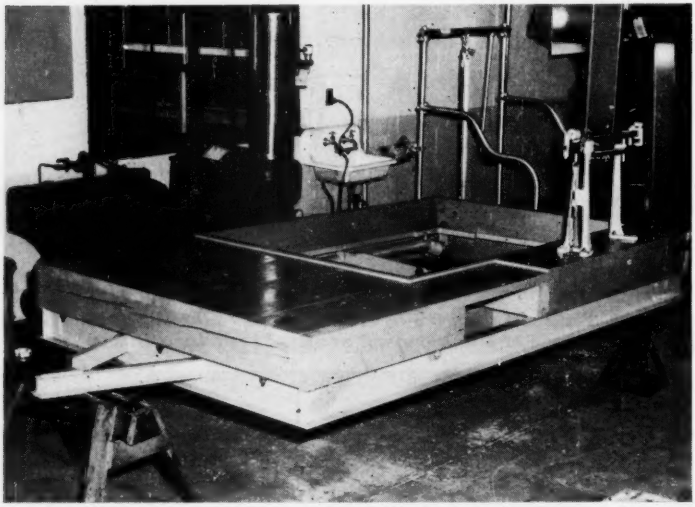

Figure 3. Weigh beam has been lowered and scale is bolted in place. Platform in front of scale is planked over. The opening above the channel iron in front of the weigh beam is made into a tool box to hold the weights, jacks, etc.

The loading and unloading ramps are hinged to the trailer and can be folded onto the trailer for transit (figure 7 and 8).

The doors are hinged to close in front and back of the sides of the weighing-crate rather than between the sides. This allows the use of the full length of the scale platform. The front door is equipped with a cattle stock. This comes in handy for ear tagging, tattooing or the reading of ear numbers.

The trailer axle has a 4-inch drop and was obtained from the Foreman Manufacturing Co., 5353 South State St., Chicago 9, Ill. It can be obtained in nearly any specified width. The overall width

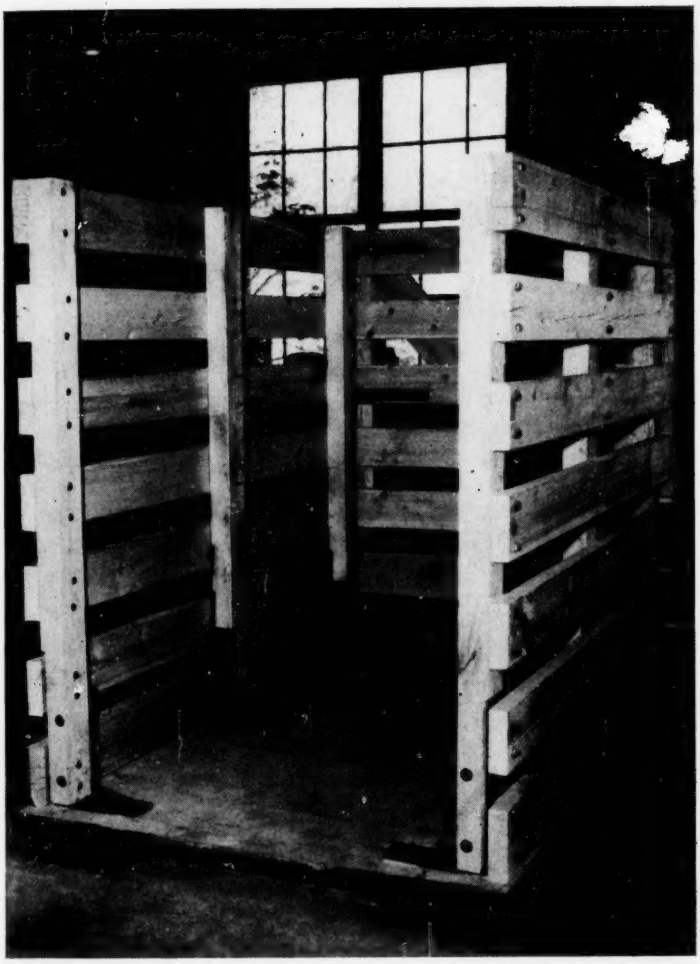

Figure 4. Detail of fastening the sides of the crate to the scale platform.

of the unit is 92 inches. Tires are 15″ × 7.50″, 8 ply, and are ample to carry the load. The springs are underslung to bring the scale platform as low as possible. The height in this case is 29 inches above the ground. The axle is placed in such a manner that about 235 pounds are on the draw bar. Two men can easily lift the draw bar

and hook it onto the truck. A wooden shield is fastened to the bottom of the scale with four bolts. This prevents road dirt from accumulating in the scale mechanism and can be speedily removed if necessary (figure 7). The scale has proved to be extremely accurate. Four screw jacks are carried to level and support the scale when disconnected from the truck. However, the scale needs only to be approximately level. Its accuracy is not affected when deviating slightly

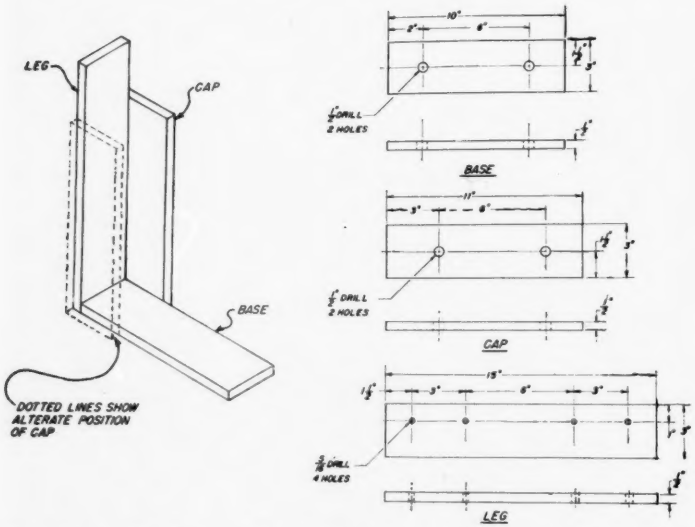

Figure 5. Detail of custom built angle irons which support the weighing crate.

from the horizontal. Figure 8 shows the scale in use with the screw jacks in position.

The trailer tows with ease at 45 m.p.h. The electric brakes are necessary, otherwise it is difficult to stop without putting undue stress on the truck's braking system. The gross weight of the complete unit is 3500 lbs. Although the doors have a self-locking catch, a three-eighth inch bolt and wing nut are placed through the frame and door when the scale is in transit. This prevents the accidental opening of the doors and gives extra support to the sides of the weighing-crate when the turn buckles are tightened.

The scale is easily set up and quickly made ready for transit.

Cattle up to 2,000 lbs. and 2,500 lb. horses have been weighed with ease. It has also been used for weighting sheep and hogs.

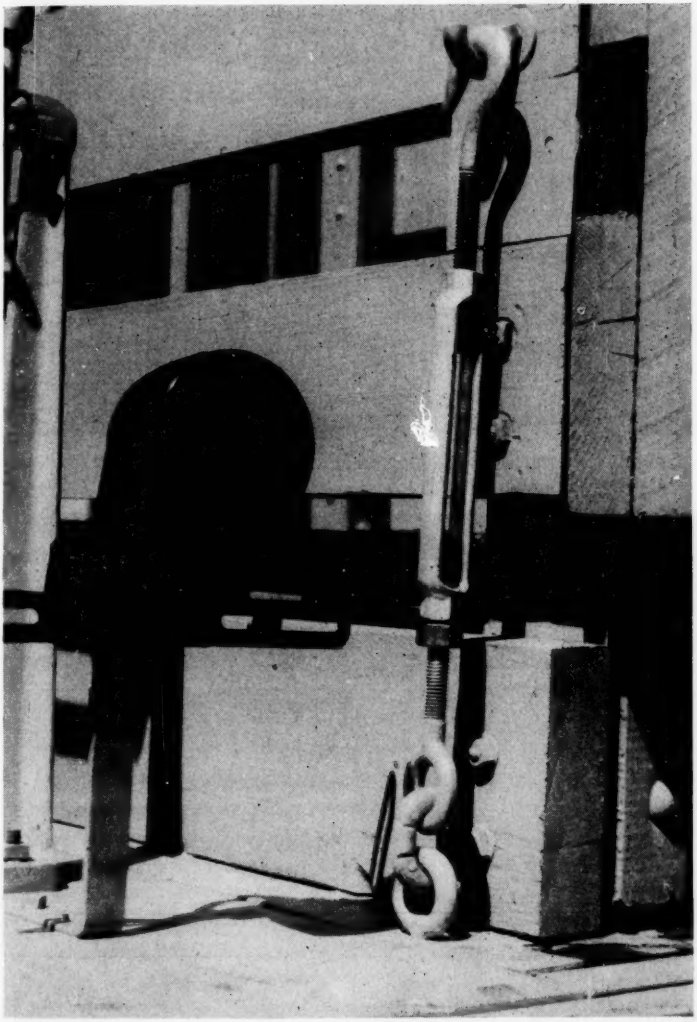

Figure 6. Turnbuckles are adjusted to about 3500 lbs. of pressure when scale is in transit.

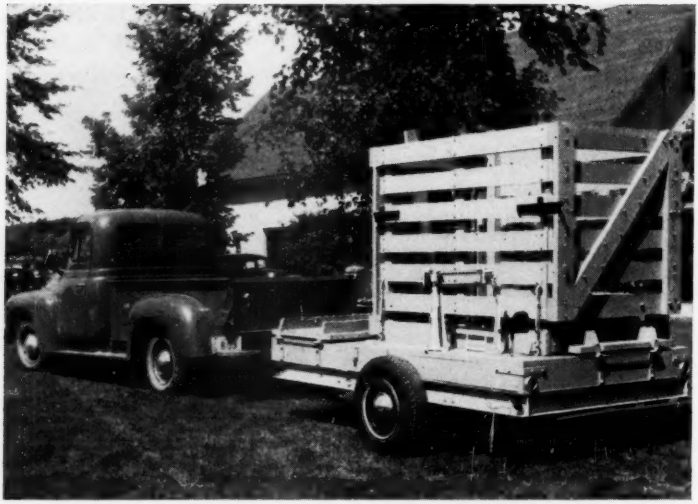

Figure 7. Complete unit ready for the road.

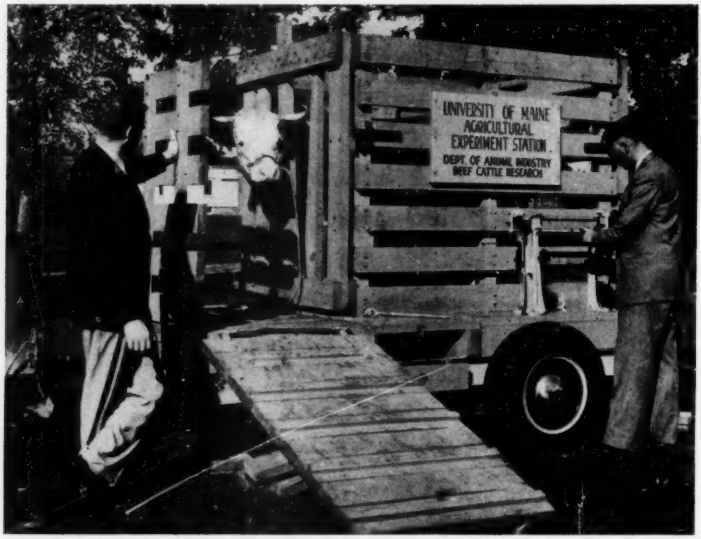

Figure 8. Scale in operation, fastened to the truck and jack screws in place.

GENETIC VARIATION IN SERVICES PER CONCEPTION AND CALVING INTERVAL IN DAIRY CATTLE [1]

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CONSIDERABLE conflict exists among breeders and even among research workers as to the attention reproductive efficiency should receive in dairy cattle selection programs. The need for regular calving to maintain efficient milk production is apparent, but clarification of the relative importance of genetic and environmental influences in maintaining high reproductive performance is lacking.

Measures of reproductive efficiency such as services per conception, calving interval, days from first breeding to conception and percentage indexes based on a calf each twelve months, have been studied. Trimberger and Davis (1948), Old *et al.* (1949), Tabler *et al.* (1951) and Dunbar and Henderson (1950) found little genetic variability in services per conception. Berge (1942), however, found a significant intra-cow repeatability of services per conception. Gaines and Palfrey (1931) and Ostergaard (1942) report small though significant values for the repeatability of calving interval length. The heritability value of zero, reported by Dunbar and Henderson (1950), suggests that the basis for this intra-cow repeatability is not due to transmissible hereditary differences.

This study was undertaken to clarify further the importance of genetic variation in reproductive efficiency in dairy cattle as measured by services per conception and the length of the interval between calvings.

Experimental

Individual records of the reproductive histories of cows in 12 North Carolina State owned dairy herds furnished the data for this study. These herds represent a cross section of the various climatic and soil conditions which exist in the State from the mountains in the West to the sandy coastal plain in the East. No herd-wide outbreaks of Brucellosis were experienced during the collection of these data,

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[2] The author gratefully acknowledges the assistance of the computing service of the Department of Experimental Statistics.

although *vibrio fetus* infection was diagnosed in four of the herds in 1950 and 1951.

In the routine processing of these data after each lactation record was completed, identifying information, production record, services per conception and calving interval (days) were punched in International Business Machine cards. For this study only data where complete calving records were available were used in determining

TABLE 1. SUMMARY OF SERVICES PER CONCEPTION AND CALVING INTERVALS BY HERD-BREED GROUPS

		Service per Conception		Calving Interval	
Herd	Breed [1]	Number Observations	Mean	Number Observations	Mean
1	A	11	1.91	5	374
1	G	171	2.02	150	418
1	H	158	1.93	162	414
1	J	309	1.70	313	392
2	H	24	1.67	28	407
3	H	191	1.69	301	421
4	H	32	1.66	46	438
5	H	125	1.58	264	381
6	H	63	2.02	174	401
7	H	27	1.37	8	446
8	H	20	1.60	18	404
9	H	107	1.97	54	388
10	G	36	2.31	29	441
10	J	357	1.88	340	405
11	A	470	1.74	314	413
12	J	342	1.79	213	414
Totals		2419	1.80	2443	406

[1] A—Ayrshire, G—Guernsey, H—Holstein, J—Jersey.

services per conception and days between calvings. Hence, services to cows eliminated for failure to breed were not included, and the study involved reproductive variability among fertile cows.

Some of the cows did not remain in the herds for a second calf, consequently the cows included in the study of services per conception were not all included in the study of calving intervals. The data included 1129 cows with services per conception for 2,443 calvings and 1016 cows with 2,419 calving intervals. The mean number of services per conception was 1.80 and the mean calving interval was 406 days. The summary of these data by herd-breed groups is given in table 1.

TABLE 2. COVARIANCE ANALYSIS OF SERVICES PER CONCEPTION FOR DAMS (x_1) AND DAUGHTERS (y_1)

Source of Variation	Degrees of Freedom	Σx_1^2	$\Sigma x_1 y_1$	Σy_1^2	Regression y_1 on x_1
Total	397	356.5	—5.1	324.6	.....
Among sires	105	136.7	—13.3	92.4	.....
Within sires	292	219.8	8.2	232.2	0.037±.060

In four of the herds the data covered an extended period during which managemental trends could have exerted some influence on the measures of reproductive efficiency studied. Repeatability was computed on a within-contemporary basis to minimize this influence on among-cow comparisons. Each contemporary group included animals of a particular breed born during a specified three year period. The intra-sire regression of daughter on dam was used to remove the possible influence of environmental trends in the daughter-dam analysis.

Results

Daughter-dam Regression

These data yielded 398 daughter-dam comparisons where information on services per conception and calving interval were available both for the daughter and her dam. When a dam had more than one daughter by the same sire only one daughter, chosen without regard to the items studied, was used. The average of all available observations was used as a measure of the dam's or her daughter's phenotypic value. The mean calving intervals for the dams and their daughters were 413 and 409 days respectively; while the mean number of services per conception were 1.88 and 1.75 respectively.

The within-sire regressions in tables 2 and 3 are presented on the basis of average phenotypic values for the dams. The average number

TABLE 3. COVARIANCE ANALYSIS OF CALVING INTERVAL FOR DAM (x_2) AND DAUGHTERS (y_2)

Source of Variation	Degrees of Freedom	Σx_2^2	$\Sigma x_2 y_2$	Σy_2^2	Regression y_2 on x_2
Total	397	1,444,949	—21,126	1,386,924	.....
Among sires	105	509,952	—12,130	456,487	.....
Within sires	292	934,991	—38,996	930,437	—0.042±.058

of conceptions used in determining services per conception was 3.82 and the average number of calving intervals was 3.93. When expressed on the basis of single observations for the dams by the relationship given by Lush and Straus (1942), the regressions are 0.013 for services per conception and –0.018 for calving interval. Doubling the regression coefficient for services per conception gives a value of 0.026 for heritability which is not significantly different from zero. The slight negative value for the regression for calving interval is indicative of sampling about zero and also indicates a heritability estimate of zero.

Analysis of Variance

The analysis of variance with the separation of the variance within contemporary groups into its individual components is summarized in table 4. The component of variance σ^2_c results from hereditary and permanent environmental influences which differ from cow to cow but are alike for the several expressions of a trait by the same cow. The component σ^2 results from those influences which differ for the several expressions for an individual cow.

Repeatability is computed as an intra-class correlation $\left(\frac{\sigma^2_c}{\sigma^2_c + \sigma^2}\right)$ and measures the tendency for observations on the same cow to be more alike than observations on different cows. In the analysis of services per conception σ^2_c was less than zero, and since the negative estimate was not interpretable, repeatability was taken to be zero. For calving internval repeatability was estimated to be $0.133 \pm .026$, a value too low to be of much practical importance.

Discussion

The low heritability estimate for services per conception points out that the variation in this measure of reproductive efficiency is non-genetic. This conclusion is further strengthened by the lack of repeatability of the number of services required for successive conceptions of the same cow. The values obtained in the present study are in agreement with those of Olds *et al.* (1949) who found the correlation for 91 daughter-dam pairs for services per conception to be —0.013. Olds and Seath (1950) found a correlation of 0.084 ± 0.012 between number of services required for conception for a cow in two successive years, but herd differences were not accounted for in their analysis. Berge (1942) reports repeatability to be $0.22 \pm .05$ for 6458 matings of 869 cows in the herd of the Norwegian Agricultural

TABLE 4. ANALYSIS OF VARIANCE OF SERVICES PER CONCEPTION AND CALVING INTERVAL

Source of Variation	Service per Conception				Calving Interval			
	D.F.	Mean Square	Expected Value of Mean Square	Variance Components	D.F.	Mean Square	Expected Value of Mean Square	Variance Components
Total	2442	1.755	.....	.....	2418	5,743	.....	...
Herd-breed groups (H-B)	15	3.295	.....	.....	15	30,815	.....	...
Contemporaries (C) in H-B	62	4.174	.....	.....	63	12,761	.....	...
Cows in C in H-B	1051	1.667	$\sigma^2+2.127\,\sigma_c^2$	0.000	931	6,419	$\sigma^2+2.350\,\sigma_c^2$	724
Within cow	1314	1.694	σ^2.....	1.694	1409	4,716	σ^2	4716

σ^2 is variance among observations on the same cow.
σ^2_c is the additional variance among observations on different cows.

College. The possibility that this value was influenced by a time trend in herd management must be considered since the data covered a 50 year period.

Dunbar and Henderson (1950), studying whether or not a cow returned to first service as a measure of fertility for 1015 cows resulting from artificial insemination in New York, found repeatability to be 0.024 and heritability to be 0.004. This measure of fertility provides much of the same information as services per conception, and the results of the present study are in agreement with theirs.

Spielman and Jones (1939) used an index of reproductive efficiency based on an ideal calving interval of 12 months. This index is almost perfectly correlated with the calving interval, especially over the range of calving intervals from 330 to 480 days in length, and would rate cows in the same respective order in the herd. These authors found the correlation between the mean reproductive efficiencies of the foundation cows and the mean reproductive efficiencies of their female descendants to be $0.546 \pm .118$. Significant breed differences were found in their study and these undoubtedly contributed to the above value. Tabler *et al.* (1951) using a comparable index of reproductive efficiency did not find significant family differences in their study which was restricted to Ayrshires. Dunbar and Henderson (1950) also found the heritability of calving interval to be zero in a study of 1036 Holsteins which is consistent with the results from the daughter-dam analysis in the present study.

The value of 0.13 for repeatability of calving interval length is in agreement with results of previous studies. Gaines and Palfrey (1939) found the correlation between successive calving intervals of a cow to be 0.088 ± 0.019. Herd differences in their data would have increased their correlation, but the selection of only those cows having ten calvings would have reduced the between cow variability and tended to reduce the value for repeatability. Ostergaard (1942) found the intra-cow repeatability to be 0.13 for the first three calving intervals of 970 Red Danish cows.

The evidence obtained from the present study as well as the evidence cited from other studies demonstrates that most of the variation in service per conception and calving interval among fertile females is non-genetic. If conception eventually take place, the cow should not be discriminated against in selection merely because more than a single service was required. There does appear to be some tendency, although not a strong one, for the cow to express some individuality

with respect to the length of her successive calving intervals. Chapman and Casida (1937) found repeatability of the period from parturition to first subsequent estrous to be 0.19 and Olds and Seath (1953) found a value of 0.29. The tendency for cows to repeat the length of this period in the reproductive cycle could account for some of the individuality regarding calving interval lengths.

Gilmore (1949) has reviewed the literature on the hereditary limitations imposed on cattle by numerous lethal and semi-lethal genes. Such genes could exert some influence on the measures of reproductive efficiency studied as they influence embryonic mortality. Presumably the frequency and influence of these genes has been restricted by strong negative selection pressures by natural agencies.

Since nature has selected, and continues to select, for improved reproduction, it may not be surprising to find a lack of genetic variability in the measures of reproductive efficiency studied. This general finding also is consistent with the evidence presented in studies with swine (Lush and Molln 1942); although natural selection undoubtedly would tolerate more variation in normal reproductive function in those species where litters rather than single births are common. It is true that many other measures of reproductive efficiency could be devised, but for dairy cattle they would rely on much of the same information provided in the two easily accessible measures studied here. Should it be possible to find a measure that would have greater genetic utility, it appears extremely doubtful that heritability could be enhanced sufficiently to warrant paying attention to variation in services per conception and calving intervals of fertile cows in evaluating them in a breeding program.

Summary

Number of services per conception and the length of the interval between calvings were studied to determine the genetic variance in these commonly used measures of reproductive efficiency. The data included 1129 cows with services per conception for 2443 calvings and 1016 cows with 2419 calving intervals. The mean number of services per conception was 1.80 and the mean calving interval was 406 days. The estimate of heritability of services per conception was 0.026, while the intra-cow repeatability was zero. Heritability of calving interval length was zero; although, repeatability was 0.133.

Evidence from this study indicates little existing genetic variability in the two measures of reproductive efficiency studied. The number of

services required for conception for one calving is of no value in predicting the number of services that will be required for a subsequent pregnancy. The length of calving interval does appear to be slightly more a characteristic of the individual cow than is services per conception. Application of genetic principles in selection for fewer services per conception or for a shortening of the length of calving interval has little to offer the dairy cattle breeder.

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RELATIONSHIP BETWEEN LEVEL OF MILK PRODUCTION AND BREEDING EFFICIENCY IN DAIRY CATTLE

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MANY dairymen are of the opinion that they experience more breeding difficulties in their high producing cows than in close relatives which produce at lower levels. Clapp (1937) observed that cows milked twice daily came into heat after calving 23 days earlier on an average than did cows milked four times daily. However, it was not ascertained whether the level of production or the frequency of milking was responsible for this difference.

New Zealand workers (Anonymous, 1940–1941), in a progress report, stated that no definite conclusions can be drawn relative to the association of poor fertility with high production. However, they reported that there appeared to be a strong suggestion of better fertility in the lower producing herds; also, that the incidence of sterility and abortion showed a definite association with the higher producing herds. Lewis and Horwood (1950) found from a study on the Michigan State College Holstein Herd that production during the previous lactation was not related to the breeding results encountered during the following lactation. They found, however, that cows beginning a lactation at a high level of production were not rebred as quickly and did not conceive as readily as those producing at lower levels.

Dresel (1935) found that injections of prolactin given to nonparous mice delayed the estrous cycle about three weeks. He concluded from his observations that suspension of the estrous cycle was caused by the pituitary hormone, prolactin. Lahr (1936) also found that anestrus may be induced during lactation in rats by prolactin. Jones (1941) reported that fertility is heritable so perhaps breeding efficiency in dairy cattle has been reduced as a result of efforts to breed for higher production.

Eckles (1929) observed the herd at the University of Minnesota over a period of 29 years and found no relationship between the level of production of the cow and conception rate or the development of sterility. Gaines (1927) studied 4,671 records from the Guernsey Herd Register and found a low correlation ($r = 0.039$) between the level

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of milk yield and the length of service period. He found that the maximum level of milk secretion was not antagonistic to the recurrence of conception. It is evident from the available literature that there is no general agreement relative to the effect of lactation upon reproductive efficiency in dairy cattle. Because of this, the present study was conducted in order to secure additional evidence on the subject.

Experimental Procedure

Data for this study were obtained from 29 herds serviced by the Kentucky Artificial Breeding Association and whose owners were D.H.I.A. members. Single records of 519 cows were included in the study. The production records were for 225 Jerseys, 208 Holsteins and 86 Guernseys. These herds are located in the major dairy counties of Kentucky and probably represent a fair cross section of D.H.I.A. herds in this state.

Milk production yield, as recorded in the D.H.I.A. barn books, was secured for the first 120 days of the lactation. The first 120-day period was used because it is customary for dairymen to rebreed their cows during this time in an effort to maintain a desirable calving interval. This period included the peak of production, since Gaines and Davidson (1926) have shown that production increases for 30–60 days after parturition and then tends to decrease throughout the remainder of the lactation period. Using the first 120 days production avoided the possible effect of gestation on milk production. Gaines and Davidson (1926) also showed that pregnancy does not cause a decline in milk production until the fourth or fifth month following conception. All production records were converted to a mature equivalent four percent FCM basis.

The term "breeding efficiency" as used in this study, is the number of services that each cow required for successful conception. Cows which had not returned for service within 120 or more days were included. Breeding efficiency records on each individual cow were obtained from the Kentucky Artificial Breeding Association. To determine the effect of the current lactation on breeding efficiency, it was necessary to obtain the number of services required for conception during the lactation in which the 120-day production record was made. The analysis of covariance, as outlined by Snedecor (1950), was employed to measure relationships as well as significance of differences.

TABLE 1. MEAN PRODUCTION AND BREEDING EFFICIENCY BY BREEDS

Breed	Number of Cows	120-Day Milk Production		Services per Conception	
		Mean	Standard Deviation	Mean	Standard Deviation
		(lb.)	(lb.)		
Jersey	225	4104	1040	1.59	0.87
Holstein	208	5051	1112	1.76	1.04
Guernsey	86	4322	797	1.71	0.93
All breeds	519	4520	1123	1.68	0.74

Results and Discussion

The production for the first 120 days of the lactation ranged from 1,519 pounds to 8,180 pounds. The number of services for conception ranged from one to six. The over-all mean production was 4,520 pounds and the mean number of services was 1.68. Variation between breeds (table 1) was relatively small, with Jerseys showing 1.59, the lowest number of services per conception, and Holsteins and Guernseys averaging about 1.7 services.

As may be seen in table 2, there is little if any indication that high production is incompatible with high fertility. It will be observed that

TABLE 2. DISTRIBUTION OF 519 COWS ACCORDING TO MILK PRODUCTION WITH THE CORRESPONDING AVERAGE NUMBER OF SERVICES FOR CONCEPTION

Lbs. of Milk (Mature Equivalent, 4% FCM For First 120 Days of the Lactation)	Number of Cows	Average Number of Services for Conception
Less than 2500	19	1.63
2500–3000	16	2.12
3000–3500	56	1.84
3500–4000	91	1.59
4000–4500	95	1.74
4500–5000	80	1.51
5000–5500	64	1.75
5500–6000	42	1.62
6000–6500	29	1.62
6500–7000	17	1.29
7000–7500	7	1.57
More than 7500	3	3.00

the best conception rate occurred among the higher producing cows (6,500–7,000 lb.), although this group included only 3.3 percent of all cows in the study. In contrast, a low production group (2,500–3,000 lb.) ranked next to bottom in breeding efficiency, averaging 2.12 services per conception.

The use of the analysis of covariance (Snedecor, 1950) revealed that there was more variation in breeding efficiency between the herds than there was within herds, even when the number of services was adjusted to a common milk production basis. Since the differences in breeding efficiency between herds was significant, one may conclude that milk production alone does not explain this variation. The over-all correlation coefficient between the level of production and breeding efficiency was —0.04. This negative relationship is relatively small and is not significant at the five percent level of probability. The regression coefficient between milk production and breeding efficiency was negative and gave an estimate that for every 1,000-pound increase in milk production the number of services required for conception could be expected to decline by 0.03 services, an insignificant amount. The correlation on an intra-herd basis was —0.001. Such a low coefficient, which is far from significant, is strongly indicative that the effect of production on breeding efficiency is practically nil.

The correlation coefficients for the 29 herds on an intra-herd basis ranged from —0.52 to + 0.79, which could conceivably indicate that milk production and breeding efficiency are apparently closely associated in some herds and are inversely related in other herds. The standard error of the over-all correlation coefficient, as determined by the method of Ezekiel (1930), was found to be 0.25. Therefore, in a normal distribution, one should expect about two-thirds of the coefficients to fall between —0.29 and 0.21. Actually, 69 percent of the coefficients were included within this range; therefore, it can be concluded that the variations in relationship from herd to herd are as one would expect in a population where the correlation between milk production and breeding efficiency is not significant.

Summary and Conclusions

A study was made of milk production and breeding efficiency of 519 cows in 29 herds which were members of the Kentucky Artificial Breeding Association and also a D.H.I.A. Of these 519 cows, there were 225 Jerseys, 208 Holsteins, and 86 Guernseys.

Production for the first 120 days after calving for the 519 cows on a mature equivalent four percent FCM basis averaged 4,520 pounds with a standard deviation of 1,123 pounds, while the mean number of services for successful conception was 1.68 with a standard deviation of 0.74.

The correlation coefficient between milk production and the number of services for conception was —0.04, a relationship not statistically significant.

When tested by the analysis of covariance so as to segregate differences due to herd and level of production, no statistical significance was found between the level of production and the number of services required for conception.

When each of the 29 herds was calculated separately, the range in the intra-herd correlation between milk production and breeding efficiency was from —0.52 to 0.79, indicating an erratic relationship. The dispersion of coefficients calculated for individual herds closely approached a normal distribution, which would occur by chance alone where no actual relationship exists.

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ERYTHROCYTE MOSAICISM IN A HEIFER RECORDED AS SINGLE-BORN

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OWEN (1945, 1946) and Owen *et al.* (1946) made the observation that certain cattle born twin, triplet, etc. have red blood cells of more than one antigenic type. Since these mixed cell-types, called mosaics, were permanent, they concluded that cells ancestral to the erythrocytes must be exchanged by and become established in embryos having a communal vascular supply. As a result of these fundamental investigations, blood typing is now used as a reliable although indirect method of determining the chorio-vascular arrangements of dizygotic twins and higher zygotic multiples in cattle. Now if death does not always involve both of a pair of embryonal or fetal twins which have exchanged hematopoietic transplants, we should expect to find certain single-born individuals which have erythrocytes of two distinctly different antigenic types. Such an individual has now been found. The present report is concerned with the evidence which has led to the conclusion that one of the two cell-types in this particular heifer was derived from a hematopoietic transplant received from a missing cotwin.

Experimental Procedure

Proof of mosaicism is obtained by separating the two or more populations of erythrocytes comprising the admixture and determining the blood types of the separate populations. The technique of separating the populations is known as "differential hemolysis". Examples of the use of this technique are given by Owen *et al.* (1946) and Stormont (1949).

Results and Discussion

Shortly after blood-typing studies were begun in the laboratory, the opportunity of utilizing animals in the large State Herd of Holstein-Friesians (Stockton, California) arose through the kind consideration of the Herdsman, Mr. M. J. Foley. This herd was noted for the accuracy and detail with which records were kept on the individual animals.

[1] At Davis.

TABLE 1. BLOOD GROUPS OF HEIFER 2534 AND HER PARENTS

Animals	Blood Group Systems [1]								
	A—H	B	C	F—V	J	L	S—U	Z	H′
2534	A_1/—	$O_3J'K'/PY_2/E'_1$	$C_1/X_2L'/X_2L'$	F/F	J/?	L/?	—/—	—/—	H′/—
Sire	A_1/—	PY_2/E'_1	C_1/X_2L'	F/F	J/J	L/L	—/—	—/—	H′/—
Dam	H/—	$O_3J'K'/D'E'_3$	C_1/X_2L'	F/F	J/?	L/?	—/—	—/—	H′/—

[1] Genetic alternatives within a system are separated by a diagonal (/). The dash sign (—) indicates an alternative recognized by its failure to react with any of the known antibodies for antigens in the particular system.

Within a period of several months, blood types were recorded for 426 animals in this herd. All single-born animals above the age of five months and all twins irrespective of age were included. The blood types were arranged on the basis of blood groups within the systems B, C, F-V, etc. (Stormont *et al.*, 1951; Stormont, 1952).

Among the 426 animals sampled in the initial study was the seven month old heifer 2534, her dam (cow 2092), and her sire (Napstahos Sir Amber Segis 855325). Although heifer 2534 was recorded as single-born, mosaicism was indicated in tests of her blood with antibodies for the blood factors P, Y and E′ of the B system and C of the C system, and also by the fact that it was necessary to postulate three alternatives in the B system to accommodate, on the basis of known B alleles, all of the blood factors in this system which were evident in her blood.

The blood groups indicated in the mosaic of 2534 and those established in her parents are recorded in table 1. The two cell-types which comprised this mosaic in 2534 are shown in table 2. Since these results were confirmed on samples drawn from 2534 at intervals of several months, there could be no doubt as to the permanence of the mosaic. The only question was how it came about.

We first considered the possibility of whether there was anything

TABLE 2. BLOOD GROUPS OF TWO KINDS OF ERYTHROCYTES IN BLOOD OF HEIFER 2534

Cell-types [2]	Blood Group Systems [1]								
	A—H	B	C	F—V	J	L	S—U	Z	H′
Type 1	A_1/—	$O_3J'K'/E'_1$	X_2L'/X_2L'	F/F	J/?	L/?	—/—	—/—	H′/—
Type 2	A_1/—	$O_3J'K'/PY_2$	C_1/X_2L'	F/F	J/?	L/?	—/—	—/—	H′/—

[1] See notes table 1.

[2] Cells of "type 1" comprized approximately 70 percent of the mosaic. These cells were separated from "type 2" by hemolysing cells of type 2 with antibodies for either or both of the blood factors Y and C. Cells of "type 2" were separated from "type 1" by hemolysing "type 1" with E′ antibodies.

in the records indicating that 2092, the dam of 2534, might have carried twins. The records simply showed that 2092 had produced one calf, a female, prior to 2534. Forty-one days following the birth of this first calf, 2092 was bred artificially to the bull "Amber". Fifty-one days following this breeding she was examined by a Veterinarian and declared to be with calf in the left uterine horn. The calf, heifer 2534, was born 275 days from the date of mating. Evidence from the herd records that 2092 might have been carrying twins or dropped twins was entirely negative.

We next considered the possibility that 2092 dropped twins and that one of these twins was claimed by a cow which gave birth to a single-born calf on that same day. Only one other cow calved on that date, and she produced a bull calf which was slaughtered shortly thereafter. If we assume that this bull was actually the twin of 2534, then, from the evidence presented, 2534 should have been a freemartin. This is denied by the fact that 2534 has, at this writing, already produced a calf. The only other cows which calved within three days of the birth of 2534 all produced bulls. Thus, any evidence that 2534 had a viable co-twin was entirely negative.

We could not rule out the possibility that 2534 had a non-viable co-twin which went undetected in the discharged placenta or the possibility that such a co-twin was resorbed or retained. In the latter event, resorption could have been underway at the time of the pregnancy examination.

Williams (1939) has written, "When the fetal sacs of bovine twins are completely fused and one fetus dies, so far as known, the death of the other promptly follows. When the two sacs are distinct one fetus may die and undergo papyraceous mummification and the other continues to live . . . etc." We have, however, obtained evidence that death of one of a pair of twins with fused chorions is not necessarily followed promptly by death of the other. Subsequent to the birth of 2534, another cow (P2194) in this same herd was bred to the sire of heifer 2534 and dropped male twins one of which was viable and the other appeared to have died sometime during the early part of the last trimester of gestation. A blood sample was collected from the viable twin (P2894) within a few hours after its birth and an attempt was made to do the same from the dead fetus. Reddish fluid collected from the heart and larger blood vessels of this fetus contained no cells. That the viable twin had received a hematopoietic transplant from its co-twin is indicated by the data given in table 3. As in the case of 2534 (table 1), both

B alleles of the sire were represented in the mosaic of this twin and, in addition, so were both of the sire's C alleles.

Finally, it was necessary to consider the possibility that twinning was not involved in the production of the mosaic. While there is no doubt that gene mutation might successfully mimic erythrocyte mosaicism associated with the birth of twins and higher multiples in cattle, mutation can be excluded as an explanation of this mosaic. Such derivation would depend not only on simultaneous mutation at two independent loci (B and C, see table 2), but also on the mutations producing precisely the alleles found in her parents.

Owen pointed out (personal communication) that Hollander (1949) had adduced evidence that certain somatic mosaics in pigeons have

TABLE 3. BLOOD GROUPS OF TWIN (P2894) AND HIS PARENTS THE CO-TWIN WAS A STILL-BORN FETUS

		Blood Group Systems [1]							
Animals	A—H	B	C	F—V	J	L	S—U	Z	H′
P2894 [2]	A_1/	PY_2/E'_1/—	C_1/X_2L'/—	F/F	J/?	L/?	—/—	Z/—	H′/—
Sire	A_1/—	PY_2/E'_1	C_1/X_2L'	F/F	J/J	L/L	—/—	—/—	H′/—
Dam	A_1/—	—/—	—/—	F/F	J/—	L/—	—/—	Z/—	—/—

[1] See notes table 1.

[2] Mosaicism was indicated in tests of the blood of P2894 with antibodies for the blood factors P, Y, E′, C, X, L′ and H′.

arisen through the incorporation of tissue deriving from supernumerary sperm into the zygotic tissue of the embryo, but that this explanation, designated by Hollander as "bipaternity", could not apply to the mosaic in 2534 since both of her cell-types clearly demonstrate a maternal contribution. However, an alternative considered by Hollander, the double fertilization of a binucleate egg and the subsequent incorporation of both zygotes into a single individual, is not ruled out by the data at hand. Genetically, this would be equivalent to the explanation based on twinning, the difference involving only the unanswered question of whether the postulated missing co-twin retained its existence as a separate individual.

In spite of this unanswered question, there were several lessons from the data on the case of heifer 2534. One concerns genes which affect blood cells. It is well known to workers in this field that when the serologic criteria for mosaicism are overlooked certain mosaic bloods can pass undetected. Should this have happened in the case of 2534, it is possible that the accepted explanation for the appearance

of both "PY" and "E'" would have been crossing-over. The exchange under this interpretation would have involved two genes believed by some to be members of the same allelic series. Carr (1945; 1947) has raised this same point in connection with the flexed-tail-anemia complex in mice where again erythrocyte mosaicism could be confused with crossing-over.

Finally we mention that the present data seem to amplify the possibility that certain single-born heifers which prove to be non-breeders may be free-martins whose co-twins were never born or went undetected in the discharged placentae. The demonstration of mosaicism in such heifers would be particularly pertinent both from the theoretical and practical point of view.

Summary

Evidence is presented for erythrocyte mosaicism in a heifer recorded as single-born. Since mutation could be excluded as a cause of the mosaic, it was concluded that one of her two cell-types was derived from a missing co-twin. The only traces of this twin were the descendants of certain of its cells found in the viable heifer.

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THE EFFECTS OF STILBESTROL, DIENESTROL, TESTOSTERONE AND PROGESTERONE ON THE GROWTH AND FATTENING OF BEEF STEERS[1]

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THE role of hormones, particularly those of the anterior pituitary and thyroid glands and the gonads, in the regulation of growth patterns of mammals has been at least qualitatively known for about two decades. Improved methods of extraction or synthesis of several of these hormones have made it possible to consider the practical applications of endocrinology in meat animal production. The marked effects of certain estrogens, particularly stilbestrol, on the rate of gain and efficiency of feed utilization of wether lambs and beef heifers prompted similar studies with beef steers.

Materials and Methods

Three experiments were conducted. Each involved 40 yearling Hereford steers divided into four groups with duplicate lots of 5 cattle each. Thus there were 10 steers per treatment in all experiments. Experiments I and II were, with the exception of one treatment, similar. As shown in tables 1 and 2 the average initial weight in the first was about 580 pounds and in the second about 680 pounds. The first experiment continued for 182 days and the second for 140 days. Both groups of animals were marketed at about 1000 lbs. The animals in the first two experiments were fed a ration of corn and cob meal (80% corn—20%cobs) two pounds of cottonseed meal and one pound of molasses feed per steer daily, clover-timothy hay, and a mineral mixture of bone meal and iodized salt.

The steers in Experiment III had an average initial weight of about 800 pounds. They were fed for 140 days to a final weight of about 1200 pounds. As shown in table 3 their ration was composed of corn silage, Purdue Supplement A and minerals.

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 725, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2] Appreciation is expressed to Armour and Company for progesterone, to Ciba Pharmaceutical Products, Inc. for the testosterone, to the Ortho Research Foundation for dienestrol and progesterone, and to Wick and Fry, Inc. for the stilbestrol used in these experiments.

Experiment I

The experimental treatments were as follows: Group I, Control; Group II, five 12 mg. stilbestrol pellets; Group III, ten 12 mg. stilbestrol pellets; Group IV, twelve 15 mg. testosterone propionate pellets

TABLE 1. EFFECT OF HORMONES ON GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY

Experiment I

Item		Group and Treatment			
		I Control	II 60 mg. Stilbestrol	III 120 mg. Stilbestrol	IV 255 mg. Testosterone
Number of steers		10	10	10	10
Av. initial wt.	lb.	583	583	575	579
Av. final wt.	lb.	990	1031	1067	976
Gain per steer	lb.	407	448	492	397
Daily gain per steer	lb.	2.24	2.46	2.68	2.18
Daily Feed Consumption per Steer					
Corn and cob meal	lb.	16.30	17.35	17.42	15.93
Cottonseed meal	lb.	1.95	1.95	1.95	1.95
Molasses feed	lb.	.85	.85	.85	.85
Clover-timothy hay	lb.	7.94	7.96	8.23	7.97
Mineral mix	lb.	.11	.14	.15	.12
Salt	lb.	.10	.10	.11	.09
Total	lb.	27.25	28.35	28.71	26.91
Feed per 100 Pounds of Gain					
Corn and cob meal	lb.	728	704	650	731
Cottonseed meal	lb.	87.2	79.3	72.9	89.7
Molasses feed	lb.	37.8	34.3	31.3	38.8
Clover-timothy hay	lb.	355	323	307	366
Mineral mix	lb.	5.0	5.8	5.5	5.3
Salt	lb.	4.5	4.2	4.1	4.2
Total	lb.	1217.5	1150.6	1070.8	1235.0

at the beginning of the experiment and an additional five pellets on the 96th day of the experiment.

Experiment II

The treatments of Groups I, II and III were identical with those in the first experiment. Group IV received eight 10 mg. pellets of dienestrol rather than testosterone as the first experiment.

Experiment III

Group I, Control; Group II, nine 12 mg. stilbestrol pellets; Group III, five 12 mg. stilbestrol pellets at the start of the experiment and eight 25 mg. pellets of progesterone 14 days later; Group IV, 120 mg. of dienestrol plus 300 mg. of progesterone in a semi-solid injectable base. All hormones were administered subcutaneously in the neck.

TABLE 2. EFFECT OF HORMONES ON GROWTH RATE, FEED CONSUMPTION AND EFFICIENCY

Experiment II

Item		Group and Treatment			
		I Control	II 60 mg. Stil-bestrol	III 120 mg. Stil-bestrol	IV 80 mg. Dien-estrol
Number of steers		10	10	10	10
Av. initial wt.	lb.	675	680	673	676
Av. final wt.	lb.	1034	1086	1096	1083
Gain per steer	lb.	359	406	423	407
Daily gain per steer	lb.	2.56	2.90	3.02	2.91
Daily Feed Consumption per Steer					
Corn and cob meal	lb.	17.11	17.32	18.14	17.23
Cottonseed meal	lb.	1.96	1.96	1.96	1.96
Molasses feed	lb.	1.00	1.00	1.00	1.00
Clover-timothy hay	lb.	6.90	7.66	7.72	7.05
Mineral mix	lb.	.09	.10	.13	.09
Salt	lb.	.04	.05	.06	.05
Total	lb.	27.10	28.09	29.01	27.38
Feed per 100 Pounds of Gain					
Corn and cob meal	lb.	667	597	600	593
Cottonseed meal	lb.	76.3	67.4	64.7	67.3
Molasses feed	lb.	39.0	34.4	33.1	34.4
Clover-timothy hay	lb.	269	264	255	242
Mineral mix	lb.	3.6	3.6	4.2	3.3
Salt	lb.	1.7	1.8	2.0	1.7
Total	lb.	1056.6	968.2	959.0	941.7

The cattle were weighed individually at 28-day intervals during the experiment. The average daily feed consumption is shown in the accompany tables. Dressing percentage and Federal carcass grades were obtained. The data on growth rate and feed efficiency were analyzed by the method of analysis of variance.

Results and Discussion

Growth Rate

The effects of the various hormones are summarized in tables 1, 2 and 3. There was a significant ($P < .05$) increase in daily gain in the steers which received 60 mg. of stilbestrol in experiments I and II.

TABLE 3. EFFECT OF HORMONES ON GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY

Experiment III

Item		Group and Treatment			
		I Control	II 108 mg. Stilbestrol	III 60 mg. Stilbestrol + 200 mg. Progesterone	IV 120 mg. Dienestrol + 300 mg. Progesterone
Number of steers		10	10	10	10
Av. initial wt.	lb.	790	809	806	802
Av. final wt.	lb.	1140	1240	1219	1170
Gain per steer	lb.	350	431	413	368
Daily gain per steer	lb.	2.50	3.07	2.95	2.62
Daily Feed Consumption per Steer					
Corn silage	lb.	51.88	58.85	56.78	54.13
Purdue Supplement A	lb.	3.50	3.50	3.50	3.50
Mineral mix	lb.	.16	.14	.16	.13
Salt	lb.	.07	.07	.06	.06
Total	lb.	55.61	62.56	60.50	57.82
Feed per 100 Pounds of Gain					
Corn silage	lb.	2071	1913	1929	2061
Purdue Supplement A	lb.	139.7	113.8	118.9	133.3
Mineral mix	lb.	6.2	4.7	5.4	5.2
Salt	lb.	2.7	2.2	2.2	2.2
Total	lb.	2219.6	2033.7	2055.5	2201.7

The administration of 108 mg. of stilbestrol in the third experiment or 120 mg. of stilbestrol in the other trials resulted in a highly significant ($P < .01$) increase in gain.

The administration of 60 mg. of stilbestrol in combination with 200 mg. of progesterone pellets also produced a marked improvement in rate of gain ($P < .01$).

The steers which received a total of 255 mg. of testosterone propi-

onate did not gain as rapidly as the controls. This is in contrast with the report of Burris *et al.* (1952) that testosterone produced a slight increase in rate of gain of steers. These investigators, however, employed a different form of hormone administration and used a far greater amount than was used here (1 mg. per kg. of body weight weekly). The use of 80 mg. of dienestrol pellets in experiment II did improve gain ($P < .05$) but dienestrol and progesterone in combination in an injectable base had no significant effect over the entire experimental period. Inspection of the monthly weight records shows that during the first two months of treatment the dienestrol groups gained at a greater rate than the controls. It appears safe to assume that dienestrol in this injectable base did not have as prolonged an effect as either stilbestrol or dienestrol pellets. A similar observation has been reported in lambs (Andrews and Beeson, 1953).

Feed Consumption and Efficiency

There has been a consistent reduction in the feed required per unit of gain in all stilbestrol treated animals in each of the three experiments. The improvement in feed efficiency was highly significant ($P < .01$) in the animals which received 120 mg. in experiment I and significant ($P < .05$) in the corresponding groups in experiment II. The differences required for statistical significance are high but the trend in improvement of feed efficiency in all hormone-treated groups is evident. These data confirm the reports of Dinusson *et al.* (1950) in beef heifers and Andrews *et al.* (1949, 1953), Jordan (1950) and O'Mary *et al.* (1952) in lambs that stilbestrol treatment does improve feed efficiency. Dienestrol pellets at a level of 80 mg. per steer also improved feed efficiency ($P < .05$).

Carcass Studies

Data on carcass quality as determined by official Federal grades and dressing percent are presented in table 4. These data do not lend themselves to statistical analysis. It is evident, however, that there are no significant differences in dressing percentage of any of the groups in either experiment. In lambs dressing percent has been consistently lowered by stilbestrol as has carcass grade (O'Mary *et al.*, 1952, Means *et al.*, 1953). In experiments I and II with beef steers it seems obvious that carcass grade is reduced by stilbestrol at either the 60 or 120 mg. level. The effects of 80 mg. of dienestrol are inconclusive due to limited data.

The growth data and feed efficiency data in Experiment III were obtained at the end of 140 days of experimentation. The heavier animals were marketed on April 4, 1952 and the remainder on May 12, 1952.

TABLE 4. EFFECT OF HORMONES ON CARCASS YIELD AND GRADE

Item	I Control	II 60 mg. Stil-bestrol	III 120 mg. Stil-bestrol	IV 255 mg. Testost-erone
	Experiment I			
Dressing percentage	59.9	60.1	59.9	60.50
Carcass grades, number [1]				
U. S. choice	...	...	...	...
U. S. good	9	8	5	9
U. S. commercial	1	2	4	1
	Experiment II			80 mg. Dien-estrol
Dressing percentage	62.4	62.8	62.8	62.1
Carcass grades, number [2]				
U. S. choice	10	5	7	9
U. S. good	...	4	3	1
U. S. commercial	...	1	...	...
	Experiment III		60 mg. Stil-bestrol+ 200 mg. Prog-esterone	120 mg. Dien-estrol+ 300 mg. Prog-esterone
	Control	108 mg. Stil-bestrol		
Dressing percentage	62.18	61.96	61.40	61.28
Carcass grades, number [3]				
U. S. prime	3	1	...	2
U. S. choice	6	9	10	8

[1] One Steer from Lot III was not marketed with the group.
[2] The Federal grading system was changed on January 1, 1951. The 1950 grades of Good and Commercial became Choice and Good respectively in 1951.
[3] One Steer from Lot I was not marketed because of an injury which required local slaughter.

Only one steer from the control treatment was slaughtered on April 4, in comparison with 6 from Lot II, 7 from Lot III and 4 from Lot IV. All of the prime animals were from the group sold on May 12. The conclusions which may be drawn are that the stilbestrol treated

cattle reached market weight sooner than the controls and graded choice or better. The later marketing date for the controls was advantageous for this group.

Miscellaneous Effects

One of the criticisms of practical livestock producers of stilbestrol-treated steers is the unevenness of the top line produced by elevation of the tail head. This change was noticed as early as the second week following treatment and was maximum at one month. The tail head tends to become normal with time but in some instances was still noticeably raised at the end of 182 days. This condition has long been known to be associated with cystic ovaries and nymphomania in cattle. It is usually observed in dairy cattle treated with stilbestrol to induce lactation. Marshall *et al.* (1948) reported that stilbestrol may induce relaxation of the broad ligaments between the sacrum and ischium. In extreme cases there may be partial dislocation of the illio-sacral cartilage and difficulty in locomotion in dairy cattle. Meites (personal communication) observed that when dairy cattle were treated with both stilbestrol and progesterone that elevation of the tail head was reduced. With the amounts of progesterone used in Experiment III we were unable to prevent the pelvic changes. This might be explained on the basis of inadequate progesterone or improper stilbestrol-progesterone ratio. During the first two to three weeks the estrogen treated steers exhibited estrous behavior. This did not reduce feed intake or growth rate and caused no particular difficulty.

Stimulation of the mammary gland usually occurs in stilbestrol-treated animals. In beef steers slaughtered 140 days after injection the only grossly observable effect was an increase in teat length. In the untreated cattle the teats were about ½ inch long and in the treated steers ranged from ¾ to 1½ inches. Beef heifers treated with stilbestrol and fed in dry lot showed marked mammary stimulation. Lactation did not occur and no difficulty was experienced (Dinusson *et al.*, 1950). The authors have observed excesive mammary development, including lactation, in beef heifers treated with stilbestrol while grazing spring and summer pastures. In another group of heifers treated while grazing on a fall pasture mammary development was limited and caused neither management nor marketing problems. It is obvious that lactation might constitute a serious problem in fattening cattle and that noticeable mammary development would probably

reduce the selling price at marketing. Perry *et al.* (1951) observed marked mammary development including lactation in stilbestrol-treated suckling lambs. The effects were most prominent one month after treatment. At the end of two months there were no noticeable effects. No management problems were encountered.

Summary

Three experiments involving a total of 120 beef steers were conducted.

Rate of gain was significantly increased by the subcutaneous administration of 60, 108 or 120 mg. of stilbestrol pellets, 60 mg. of stilbestrol pellets in combination with 200 mg. of progesterone pellets, or 80 mg. of dienestrol pellets.

Feed efficiency was consistently improved by all levels of stilbestrol or dienestrol pellets. However, the increased efficiency was not statistically significant at the 60 mg. level of stilbestrol.

The administration of 255 mg. of testosterone pellets or dienestrol and progesterone in combination in a semi-solid injectable base did not improve rate of gain or feed efficiency.

In experiments I, II and III stilbestrol, dienestrol and testosterone had no effect on dressing percentage. There was a reduction in carcass grade of some of the stilbestrol-treated steers.

Among the undesirable side effects of stilbestrol treatment are the elevation of the tail head and the resulting unevenness of the topline. The onset, degree of change and duration vary with individual animal and time. In steers fed in dry lot undesirable mammary changes were not encountered.

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THE ACTION OF STILBESTROL ON THE GROWTH RESPONSE IN RUMINANTS

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DURING recent years, numerous investigators have reported marked increases in rate of gain and efficiency of food utilization in beef heifers (Dinusson *et al.*, 1950), steers (Andrews *et al.*, 1950), and lambs (Andrews *et al.*, 1949; Jordan, 1950; Perry *et al.*, 1951; O'Mary *et al.*, 1952). The mechanism by which these marked increases in growth rate, as a result of stilbestrol implants in ruminants, are brought about, poses an interesting problem. That estrogen exerts an influence on the anterior pituitary is well accepted. For instance, in rats the growth inhibition obtained by estrogen treatment is due to a depression of the growth stimulating power of the hypophysis (Spencer *et al.*, 1932); Reece and Leonard, 1939); thyrotrophic activity is increased (Victor and Anderson, 1938); and adrenocorticotrophic activity is stimulated (Selye *et al.*, 1935; Ellison and Burch, 1936; Allen, 1942). This study was undertaken to determine whether these effects could also be demonstrated in ruminants.

Material and Methods

Many of the trials were carried out in the field with the assistance of cooperators and the Agricultural Extension Service. It was necessary to adapt the method by which the experiment was conducted, therefore, to best suit the available means at hand. In addition to these field trials, two carefully controlled experiments were conducted at this Station.

General Procedure

Each experiment was carried out following a general broad program. Variations in the procedure concerned the age and sex of the

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animal, the dosage, the initial weight, the type of ration, and the length of the experimental period. The cattle used were of the Hereford breed and the sheep were Hampshire lambs. Information concerning the number of trials, type of animals, dosage, length of experimental period and the ration is given in table 1. All the pellets used weighed approximately 12 mg. apiece and were administered with a poultry pellet implanter.

The details of the ration for each experiment are as follows:

Experiment I: 60% barley, 10% molasses dried beet pulp, 10% cottonseed cake, 20% silage, alfalfa hay *ad libitum*; Experiment II: 1% cottonseed hulls, 15% fish meal, 3% barley, 3% molasses dried beet pulp, 70% wet beet pulp, 1% molasses mill run, 1% bone meal, 6% hay; Experiment III: pasture—ladino clover and grass, supplement—last 50 days: 3 to 4 lb. of barley per head per day; Experiment IV: 35% alfalfa hay, 5% bean straw, 22% barley, 3% almond hulls, 4% molasses, 5% beet pulp, 10% milo, 16% citrus pulp; Experiment V: pasture—ladino clover and grass, supplement 5 lb. barley per head per day and hay *ad libitum*; Experiment VI: pasture—mostly tall fescue, supplement—first 90 days: 1 lb. barley and 3 lb. ladino straw per head per day and molasses *ad libitum*; Experiment VII: 70% concentrate and 30% roughage (details of ration not available); Experiment VIII: pasture—native irrigated meadow, supplement—none; Experiment IX: 20% barley, 8½% prunes, 11½% corn, 10% molasses, 7% cottonseed meal, 31% volunteer hay, 12% alfalfa hay; Experiment X: 42% barley (ground), 15% molasses dried beet pulp, 3% cottonseed meal, 25% alfalfa hay, 15% oat hay; Experiment XI: 42% barley (ground) 15% molasses dried beet pulp, 3% cottonseed meal, 25% alfalfa hay, 15% grain hay; Experiment XII: pasture—mixed grass and ladino clover, supplement—none.

The general procedure followed was to divide the animals randomly into two groups, one to serve as controls the other to be treated. Where possible the groups were separated so that average feed consumption data could be taken. This was not possible in experiments I, III, V, VI, and VIII. In most cases, the animals were weighed on the day of treatment and at thirty day intervals thereafter until cessation of the experiment. In a few of the experiments the animals were not individually identified so that only average group weights were available. In experiments III, IV, X and XI, however, individual weights were taken. Twelve hours before weighing all feed and water was withheld in order to obtain uniform weighing conditions. This practice was not followed in experiments VI, VII, IX, and XII.

During the course of the experiment, the animals were observed for effects of treatment. Where possible, slaughter data were obtained concerning carcass grades and dressing percentages. At this time the

TABLE 1. A GENERAL OUTLINE OF THE PROCEDURE FOLLOWED IN EACH EXPERIMENT. ALL TREATED ANIMALS RECEIVED STILBESTROL PELLETS IMPLANTED SUBCUTANEOUSLY

Experiment Number	Animals Used	Number of Treated Animals [1]	Average Initial Weight	Dose [2]	Length of Experimental Period	Ration [3]
			lb.	mg.	days	
I	Heifers, yearling	40	504	60	135	Hay and concentrates
II	Steer, 2-year	32	842	60	135	" " "
III	" " "	20	779	120	180	Irrigated pasture
IV	" " "	30	875	120	115	Hay and concentrates
V	" " "	36	784	60	196	Irrigated pasture and concentrate supplements
VI	Heifers, yearling	50	490	60	123	Irrigated pasture and concentrate supplements
VII	Steers, yearling	44	699	60	115	Hay and concentrates
VIII	" "	48	565	60	111	Irrigated pasture
IX	Steers, 2-year	20	962	60 [5]	91	Hay and concentrates
X	Heifers, yearling	5	553	60	107	" " "
X	" "	5	506	60 [4]	107	" " "
XI	Steers, 2-year	10	898	60 [5]	71	" " "
XII	Ewe lambs	41	64	24 [5]	71	Irrigated pasture
XII	" "	25	65	12 [5]	71	" "
XII	Wether lambs	34	65	24 [5]	71	" "
XII	" "	17	66	12 [5]	71	" "

[1] In all instances approximately an equal number of animals served as controls.
[2] All implants were administered subcutaneously in the neck unless otherwise noted.
[3] Details of the diet for each experiment are given in Materials and Methods.
[4] 66 days after the first implantation of 60 mg. these animals received a second treatment of an additional 60 mg.
[5] In these experiments pellets were implanted subcutaneously in the ear.

pituitaries, adrenals, ovaries, and thyroids were removed, dissected free of extraneous tissue, and weighed to the nearest 0.1 gm. All of the glands from both treated and control animals were retained for histological study except the pituitaries in which case only a few from each group were fixed and the rest were saved for assay purposes. The details in regard to procedures for specific experiments will be discussed under the appropriate headings.

In experiment X, 66 days after the initial implantation, the treated heifers were subdivided by random selection into two groups of five heifers each, (lots IA and IB). Lot IA was reimplanted with an additional 60 mg. of stilbestrol into the neck. Lot IB sustained no further treatment and was used as a control for the reimplanted group.

In experiments X and XI, the cattle were weighed at 14-day intervals. Concentrates were fed *ad libitum* and the hay was offered slightly in excess of that amount which was consumed by the group. The excess feed remaining was reweighed every 3 days in order to determine the amount of feed consumed by each group.

The lambs of experiment XII were divided into groups according to sex and treatment. The stilbestrol was administered at two dose levels, 12 and 24 mg. Shortly before slaughter, blood smears were made upon representative samples of each group and stained for differential cell counts.

Method of Nitrogen Balance Study

Two steers, one a purebred Aberdeen Angus and the other an Angus-Hereford cross, were treated by implantation in the ear with 60 mg. of stilbestrol (five 12-mg. pellets). Two others, an Aberdeen Angus and an Angus-Hereford cross, were used as controls. The animals were maintained on a constant food intake consisting of a daily ration of 5.6 lb. of ground barley, 2.0 lb. of molasses dried beet pulp, 0.4 lb. of cottonseed meal (43% protein), 6.0 lb. of chopped alfalfa hay and 3.0 lb. of chopped good grain hay. For a 10-day period prior to being placed in the metabolism stalls they were maintained on this experimental ration. Feces and urine were collected daily for a 7-day period. The weight of the feces was recorded and a 2 percent sample was saved each day. The daily samples were composited at the end of a week and total nitrogen was determined. The feces samples were treated with dilute formalin to prevent loss of nitrogen and the urine was acidified by the addition of 50.0 ml. of concentrated HCl. Before analysis both feed and feces were dried to a constant

weight and percent moisture was determined. After drying, the samples were finely ground in a Wiley mill to assure adequate mixing.

The collection periods were divided into 3 phases: (1) 7-day period before treatment, (2) 7-day period ending 2 weeks after treatment, and (3) 7-day period ending 4 weeks after treatment.

All samples were analyzed for total nitrogen by the Kjeldahl method.

Once every two weeks a sample of blood was taken by bleeding into a flask containing sodium oxalate. The oxalated blood was centrifuged and the plasma decanted. This material was analyzed for blood lipids by essentially the same method of Allen (1934).

Histological Methods

The procedures of fixing and staining the collected tissues were carried out routinely. Fixation was done in Bouin's, Susa and Zenker-formol. After dehydration the tissues were embedded in paraffin and sectioned at 6 to 8 micra. All sections of the pituitary glands were stained according to the method of Severinghaus (1932). In all cases, sections were made as nearly as possible in the medial sagittal plane in order that comparisons between the treatments could be made.

Preparation of Glands

The pituitary glands were frozen immediately in solid carbon dioxide following their removal from the carcass. The posterior lobe was removed and the total weight of the anterior lobe recorded. The anterior lobes were triturated in a Waring blender in a minimum volume of sterile physiological saline such that the final concentration was approximately 80 mg. per ml. The mixture was centrifuged and the supernatant was saved for assay. This procedure was varied for the glands obtained from the steers of experiment XI. In this instance the pituitaries were wrapped in aluminum foil and frozen in a mixture of solid carbon dioxide and propylene glycol. Following freezing the posterior lobe was removed and discarded and the anterior lobe refrozen and lyophilized. The desiccated gland was ground to a fine powder in a mortar and pestle. For assay the material was suspended in physiological saline before injections.

Assay Methods

In all assay procedures, rats stemming from the Long-Evans strain and inbred by brother-sister matings for approximately 15 generations were used.

Growth Hormone. Growth hormone was assayed according to the method of Greenspan *et al.* (1949), which depends upon the increase of the width of the epiphyseal cartilage plate in the tibias of immature female rats hypophysectomized at 24 days of age and receiving the material to be assayed two weeks post operative. All injections were made intraperitoneally.

Adrenocorticotrophic Hormone. Adrenocorticotrophic hormone was assayed according to the method of Moon (1940) which depends upon the increase in adrenal weight and regression of thymus weight in 4-day-old rats. Injections were made intraperitoneally once daily for 4 days. Twenty-four hours following the last injection the rats were necropsied.

Results

Influence of Stilbestrol on the Growth Response of Cattle Under Different Dietary Regimes

On Irrigated Pasture. From table 2 the results of experiments III, VI, and VIII establish that stilbestrol treated steers and heifers when grazed on irrigated pasture without heavy supplementary feeding do not make a significant increase in gain over the control groups. On the other hand, in experiment V when two-year-old steers on irrigated pasture were supplemented daily with an average of 5 pounds of rolled barley per head per day plus cereal hay *ad libitum* they made a noticeably better gain than those animals which were not treated with the hormone. This rate of gain over a period of 196 days was .23 of a pound per day more than the untreated group. Thus, if the growth response as a result of stilbestrol treatment is to be recognized, sufficient high energy nourishment must be supplied in order that these excess gains may become apparent. It should be noted, however, that the increase in total gain of the treated cattle was slightly more than the controls in all cases even though heavy supplementary feeding was not practiced.

In view of the fact that in most of the trials it was impossible to obtain individual weights no statistical analysis could be made to test the significance of these slight increases. In experiment III, however, the steers were identified, and weighed individually, thus affording an opportunity for statistical treatment. The average gains of the treated animals when compared with those of the non-treated showed no significant difference as a result of implantation of 120 mg. of stilbestrol.

TABLE 2. THE EFFECT OF STILBESTROL ON RATE OF GAIN OF STEERS AND HEIFERS ON IRRIGATED PASTURE [1]

Experiment Number	Number of Animals	Age	Days on Feed	Average Initial Weight	Gain per Animal	Average Daily Gain	Supplement
		years		lb.	lb.	lb.	
			Heifers				
VI							
Control	50	1	123	490	156	1.26	First 90 days: 1 lb. barley and 3 lb. ladino clover straw.
Treated	50	1	123	490	161 [2]	1.31	Last 33 days: 3 lb. barley, 3 lb. ladino straw and molasses *ad libitum*
			Steers				
III							
Control	20	2	181	757	317	1.76	Last 50 days: 3–4 lb. barley
Treated	20	2	181	779	338 [3]	1.97	
VIII							
Control	47	1	111	578	167	1.50	None
Treated	48	1	111	565	175 [2]	1.57	
V							
Control	35	2	196	793	364	1.86	5 pounds barley and cereal hay *ad libitum*
Treated	35	2	196	784	410 [2]	2.09	

[1] All treated animals received an implantation of 60 milligrams of stilbestrol except experiment III steers which received 120 milligrams.
[2] Animals were not individually weighed, thus no test for significance was possible.
[3] In this case in which individual weights were taken the difference was not significant.

In Feed Lot on Concentrates and Roughage. The effect of stilbestrol treatment on rate of gain of cattle in the feed lot is summarized in table 3. The results of experiment I indicate that treatment of heifers

TABLE 3. EFFECTS OF STILBESTROL ON RATE OF GAIN OF HEIFERS AND STEERS MAINTAINED ON A RATION OF CONCENTRATES AND HAY

Experiment Number	Number of Animals	Treatment [1]	Days on Feed	Average Initial Weight	Gain per Animal	Average Daily Gain
		mg.		lb.	lb.	lb.
			Heifers			
I	40	none	135	507	245	1.83
	40	60	135	504	258 [3]	1.91
X	10	none	105	529	219	2.04
	5	60	105	553	245	2.32
	5	60; 60 [2]	105	506	264**	2.51
			Steers			
II	32	none	104	862	262	2.52
	30	60	104	842	322 [3]	3.09
IV	30	none	115	835	276	2.40
	30	120	115	840	340**	2.96
VII	30	none	115	835	276	2.40
	45	60	115	729	353 [3]	3.07
IX	20	none	91	950	178	1.96
	20	60 in ear	91	962	240 [3]	2.64
XI	10	none	70	898	176	2.52
	10	60 in ear	70	889	255**	3.64

** Increase in gain over controls is significant at the 1 percent level.
[1] Pellets were implanted subcutaneously in the neck unless otherwise noted.
[2] 66 days after the first implantation, these animals received a second treatment of an additional 60 mg.
[3] Individual records were not kept so that a statistical comparison of the difference in gain between treated and control animals was not possible.

maintained on a high concentrate ration will produce a slight increase in total gain over the untreated controls. The treated heifers fed the high concentrate rations at the end of 135 days exceeded the controls in average daily gain by only .08 of a pound. The greatest difference in rate of gain that occurred during the trial was .35 lb. obtained 78 days after implantation. At no time was this difference comparable

to that of the treated feed lot steers which averaged approximately 0.50 lb. per day per head more than the untreated controls.

In experiment X a comparison of the rate of gain between the treated heifers receiving a single implant of five pellets of hormone and the controls shows no significant increase. When, however, the average gain of those heifers which received a second implant 66 days after the first treatment is compared with the control group the additional increase is significant at the 1% level of probability.

In only two of the four trials conducted with steers were individual weights recorded. Thus a statistical difference due to the treatment could not be computed in all cases. In experiments II and VII, however, in which only average group weights were obtained, the magnitude of the average difference in gain between the treated and control animals was approximately 60 lb. at the end of the feeding period. In experiment IV individual records were kept and statistical treatment indicates a significance of the increase in gain due to the treatment to have a value of $P < .001$.

In order to assure that no residual pellets remained in the carcass, in experiments IX and XI, they were implanted in the ear which is separated from the carcass at the time of slaughter. Although individual records were not kept for experiment IX the difference in average total gain and average daily gain of the treated over the controls was markedly greater. The increase in gain of the treated animals over the controls after a 91-day feeding period was 62 lb. and the increase in rate of gain was .68 lb. per head per day. Experiment XI was a carefully controlled trial and the increased growth in the treated animals was highly significant ($P < .001$), exceeding the controls by an average of 79 lb. per head at the end of a 70 day feeding period. Figure I is a comparison of the average daily gain of the individual animals fed 70 days and clearly demonstrates the marked difference in growth rate between the treated and control steers.

The Influence of Stilbestrol on Body Weight of Lambs on Pasture

In contrast to the previous results on heifers and steers on pasture, both castrated male and intact female lambs treated with one 12-mg. pellet of stilbestrol implanted subcutaneously in the ear exceeded the rate of gain over the controls. (table 4).

The wether lambs gained .18 lb. per head per day more than the untreated controls, whereas the ewe lambs gained .12 lb. per head per day more than the untreated ewes. When two 12-mg. pellets were

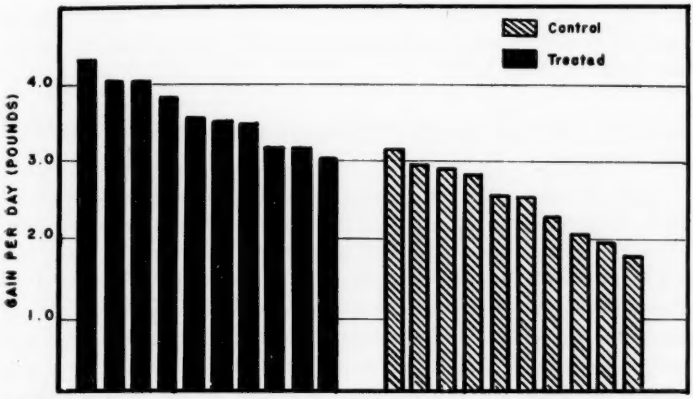

Figure 1. The average daily gain at the end of a 70-day feeding period of the individual animals in Experiment XI. Treated steers received five 12-mg. pellets implanted subcutaneously in the ear. Each bar represents an individual animal.

administered, the average daily gain of the wethers fell slightly below that of the controls. The growth rate of the ewe lambs treated with two pellets was below that of the single pellet ewes, but slightly greater than the controls. Their average daily gain was .45 lb. per head per per day as compared to .41 lb. per head per day gain by the untreated group.

Andrews (1949) administered both 12 and 24 mg. of stilbestrol to wether lambs and obtained at both dose levels a significant increase

TABLE 4. EFFECT OF STILBESTROL PELLETS ON RATE OF GAIN IN WETHER AND EWE LAMBS FED ON MIXED GRASS AND CLOVER IRRIGATED PASTURE FOR 68 DAYS[1]

Type of Animal	Number of Animals	Treatment	Average Initial Weight	Gain per Lamb	Average Daily Gain
		mg.	lb.	lb.	lb.
Wether	34	24	65.3	27.6	.41
"	35	12	61.4	40.6	.60
"	55	none	65.1	28.9	.42
Ewes	41	24	64.0	30.8	.45
"	44	12	60.7	35.8	.53
"	75	none	64.8	28.0	.41

[1] Animals were not weighed individually, thus no statistical comparison could be made.

in weight over the controls. His lambs, however, were maintained under feed lot conditions which may account for the difference in his results and those reported here.

Effect of Stilbestrol on Feed Consumption and Efficiency of Feed Utilization

Table 5 summarizes the effects of treatment with stilbestrol on feed consumption and feed consumed per hundred pounds of gain. Since the animals were separated into groups according to treatment, but not individually, feed records only represent group averages. In view of this fact no statistical analysis could be made, but, in all cases, the efficiency of feed utilization of both the treated steers and heifers was markedly increased over that of the controls. The amount of feed consumed per day was slightly greater for the treated animals than for the untreated. When the pounds of feed per hundred pounds of gain are converted to pounds of total digestible nutrient per hundred pounds of gain a comparison of the values between experiments can be made. The average amount of T.D.N. saved to produce the same gain in the treated steers was approximately 122 lbs.

Sixty mg. of stilbestrol implanted in the neck of heifers caused some increase in the efficiency of feed utilization over the controls amounting to 36 lb. of T.D.N. per 100 lb. of gain, but a greater increase amounting to a savings of 71 lb. of T.D.N. for each 100 lb. of gain was achieved when an additional 60 mg. was implanted 66 days following the first treatment. These results would indicate that in heifers more than 60 mg. of estrogen is necessary to produce a distinct response.

Although there is some increase in appetite as indicated by the elevation in feed consumption, not all the additional gain can be accounted for by this fact.

Effect of Stilbestrol Implantation on Nitrogen Retention

Table 6 summarizes the effects of stilbestrol treatment on nitrogen balance. Fecal nitrogen excretion remained unchanged throughout the trial while urinary nitrogen decreased thus indicating a true nitrogen storage. The treated steers increased their nitrogen storage by approximately .024 gm. nitrogen per kg. per day over the pre-treatment level;

TABLE 5. COMPARISON OF FEED CONSUMPTION AND FEED UTILIZATION BETWEEN STILBESTROL TREATED AND UNTREATED ANIMALS. FOR UNIFORMITY, FEED UTILIZATION HAS BEEN CONVERTED TO TOTAL DIGESTIBLE NUTRIENTS (TDN)

Experiment Number	Number of Animals	Days on Feed	Treatment [1]	Daily Feed Consumption [3]			Feed per cwt. Gain [3]	TDN per cwt. Gain
				Concentrate	Roughage	Total		
			mg.	lb.	lb.	lb.	lb.	lb.
				Heifers				
X	10	106	none	12.7	7.3	20.0	922	614
	5	106	60	11.7	8.8	20.5	891	578
	5	106	60; 60 [2]	12.0	8.9	20.9	837	543
				Steers				
XI	10	70	none	15.3	12.6	27.9	1108	706
	10	70	60 in ear	15.5	13.9	29.4	806	510
IV	30	115	none	16.8	10.7	27.5	1115	583
	30	115	120	18.2	11.6	29.8	1007	527
VII	45	115	none	19.8	8.9	28.7	1120	754
	44	115	60	20.9	9.4	30.3	987	665
IX	20	91	none	18.3	13.8	32.1	1644	1038
	20	91	60 in ear	19.0	14.3	33.3	1261	796
II	32	107	none	12.0	62.0	74.0 [4]	3065	701
	30	107	60	12.1	61.9	74.0 [4]	2450	560

[1] All implants administered subcutaneously in neck unless otherwise noted.
[2] 66 days after the first implantation of 60 mg., these animals received a second treatment of an additional 60 mg.
[3] On wet basis.
[4] This ration consited of 75 % wet beet pulp.

TABLE 6. A COMPARISON OF THE AVERAGE DAILY NITROGEN RETAINED BETWEEN STILBESTROL TREATED STEERS AND CONTROLS. COLLECTION PERIODS WERE CARRIED OUT BEFORE AND AFTER TREATMENT. STEERS WERE TREATED WITH FIVE 12-MG. PELLETS SUBCUTANEOUSLY IN THE EAR.

Collection Period	Steer Number	Daily Nitrogen Intake in Food		Daily Nitrogen Excreted in Feces		Daily Nitrogen Excreted in Urine		Nitrogen Retained	
		Treated	Control	Treated	Control	Treated	Control	Treated	Control
		gm.		gm.		gm.		gm.	
I	159	159.3		48.1		110.0		1.2	
7 days	137	151.3		46.4		88.5		16.4	
pretreatment	143		159.3		57.1		93.5		8.7
	135		159.3		48.2		102.8		8.3
	Average	155.3	159.3	47.3	52.7	99.3	98.1	8.8	8.5
II	159	160.6		52.0		68.0		40.6	
7 days	137	160.6		42.0		56.6		61.9	
ending 14	143		160.6		59.0		69.7		31.9
days after	135		160.6		46.6		82.0		32.0
treatment	Average	160.6	160.6	47.0	52.8	62.3	75.8	51.3	32.0
III	159	156.0		51.1		56.7		48.4	
7 days	137	156.0		46.2		48.0		61.8	
ending 31	143		156.0		63.0		61.9		31.1
days after	135		156.0		43.5		86.5		24.2
treatment	Average	156.0	156.0	48.5	54.2	52.5	74.2	55.1	27.7

whereas, the control steers increased their storage by only .013 gm. nitrogen per kg. per day. Thus the effect of treatment was to double nitrogen storage probably in the form of protein. The initial low

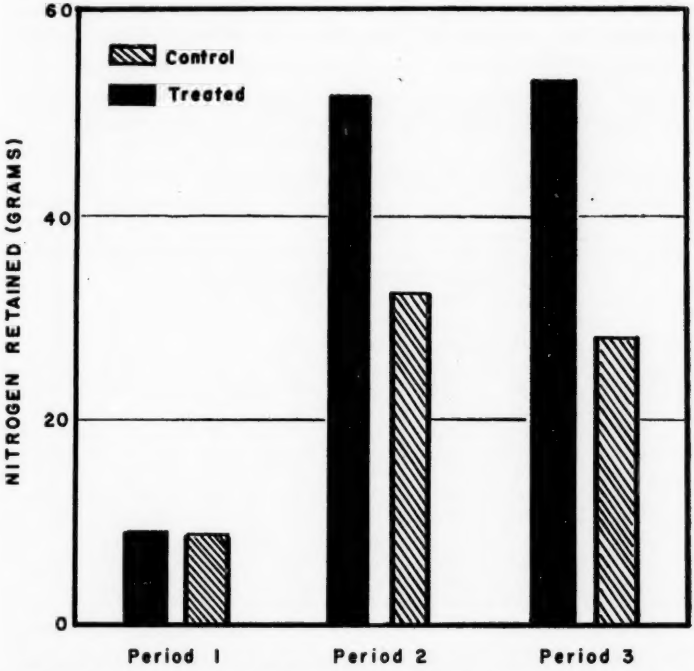

Figure 2. A comparison of the average daily nitrogen retained between treated and control steers. The values represent 3 different collection periods. Period 1—before treatment; Period 2—14 days after treatment; Period 3—31 days after treatment.

level of nitrogen retention during period I can be accounted for by the fact that the steers had not previously been confined nor acclimated to the metabolism stalls which would contribute greatly to an upset of metabolic activity. Since, however, both groups were subject to the same conditions the results are comparative. Figure 2 demonstrates these comparisons. It can be seen that following adjustment to the environment the steers showed little variation between periods while maintained on a constant nitrogen intake.

An analysis of the blood plasma for total lipid both before and after treatment yielded no differences. The average amount of blood lipids per 100 ml. of blood was 141 mg. for both treated and control animals. This result precludes the possibility that the increase in gain is due to extra fat deposition. This lack of effect of treatment has previously been reported by Dinusson *et al.* (1950) in beef heifers.

TABLE 7. COMPARISON OF CARCASS GRADE AND DRESSING PER CENT IN TREATED AND CONTROL STEERS AND HEIFERS

Experiment Number		Number of Animals	The Percent of Animals in the Following Grades:				Dressing Percent
			Prime	Choice	Good	Commercial	
			Steers				
IX	Treated	20	..	70	30	..	59.3
	Controls	20	..	80	20	..	60.1
VII	Treated	44	..	77	23	..	61.0
	Controls	45	2	94	4	..	61.0
II	Treated	30	..	53	47	..	59.6
	Controls	32	..	84	16	..	60.1
V	Treated	34	..	47	50	3	60.4
	Controls	36	..	56	44	..	59.8
XI	Treated	10	..	90	10	..	61.3
	Controls	10	20	80	..	..	61.9
IV	Treated	30	3	90	7	..	60.5
	Controls	30	23	77	..	..	60.6
			Heifers				
I	Treated	40	..	51	49	..	58.8
	Controls	40	..	84	16	..	59.8
X	Treated	10	..	70	30	..	60.5
	Controls	10	..	80	20	..	58.0

Effect of Stilbestrol on the Carcass Quality of Cattle and Sheep

In view of the marked increase in nitrogen retention it would be expected that the acceleration of protein anabolism would be reflected in changes in the carcass with respect to the ratio of protein to fat. No quantitative analysis was made to differentiate the carcass constitutents of the treated animals from that of the controls, but a comparison of the carcass grades was made which gives a rough indication of these differences. The method of grading is largely based on the amount of fat covering, the amount of internal fat, the degree of fat infiltration into the muscle fiber, the color and texture of the meat, and the conformation of the carcass. Tables 7 and 8 summarize

the data obtained. A greater percentage of the higher grades was consistently found in the untreated animals in both steers, heifers and ewe lambs.

The reasons for the failure of the treated carcasses to achieve a similar grade were as follows:

(1) The muscle fibers were larger and had a more coarse appearance. The color of the meat was a darker red than the characteristically pink appearing meat of the controls.

(2) The extent of fat infiltration between the muscle fibers known as marbling was distinctly less.

(3) The amount of both internal and external fat deposition was considerably reduced.

TABLE 8. COMPARISON OF CARCASS GRADE AND DRESSING PERCENT IN TREATED AND CONTROL LAMBS

Number and Type of Animals	Treatment	The Percent of Animals in the Following Grades:				Dressing Percent
		Prime	Choice	Good	Utility	
55 wethers	mg.	23.6	69.1	7.2	...	51.2
35 "	12	32.2	61.3	6.4	...	51.4
34 "	24	5.8	82.3	3.3	2.9	51.9
75 ewes	none	33.7	63.5	2.7	...	51.5
44 "	12	19.0	66.5	14.3	...	51.3
41 "	24	19.5	73.1	7.3	...	51.8

(4) The shoulders and rounds were heavier but the loins were lighter than the controls.

(5) The conformation was atypical. Carcasses appeared similar to that of stags, i.e., of a partially castrate animal.

There was no difference in dressing percentage (tables 7 and 8). Thus the weight increase produced by stilbestrol treatment can not be accounted for by an increase in visceral content. There was no difference in the percentage of shrink between the hot and cold carcass weights of the treated and control animals. After storage and cooling the percentage weight loss of the carcass amounted to 1.1% for the treated steers and 1.4% for the untreated controls.

Effect of Stilbestrol on the Endocrine Glands

Effect on Weight. Table 9 summarizes the data on endocrine gland weights. The pituitary glands of the treated steers were in all cases significantly larger than the controls. The adrenal glands were like-

wise significantly hypertrophied and histological measurement of the adrenal cortex indicated an increase in width due to treatment. The thyroids from the treated steers were slightly larger than the controls but no statistical significance could be shown. In those heifers which were treated with 60 mg. of stilbestrol a significant enlargement of the pituitary and adrenals occurred. In experiment I the thyroids were

TABLE 9. EFFECT OF STILBESTROL IMPLANTATION ON THE ENDOCRINE WEIGHTS OF HEIFERS AND STEERS

Experiment Number	Number of Animals	Treatment	Average Whole Pituitary Weight	Average Thyroid Weight	Average Adrenal Weight	Average Ovary Weight	Average Pituitary Anterior Lobe Weight
		mg.	gm.	gm.	gm.	gm.	gm.
			Steers				
II	32	none	2.0	21.1	18.2	....	....
	30	60	2.5**	22.5	20.2**	....	....
IV	30	none	2.2	22.6	18.5	....	....
	30	120	2.6**	23.7	21.3**	....	....
VII	44	none	1.9	....	18.1	....	....
	95	60	2.4**	....	21.8**	....	....
XI	10	none	1.9	23.5	18.3	....	1.35
	10	60	2.3*	26.1	22.4**	....	1.82**
			Heifers				
I	40	none	1.6	23.3	14.4	11.7	....
	40	60	1.8**	19.9*	15.7**	13.1	....
X	10	none	1.6	20.4	13.2	13.8	....
	5	60	2.0*	16.9	16.0	13.3	....
	5	60; 60 [1]	1.8	16.6	13.8	10.3	....

* Difference in weight in favor of stilbestrol treatment was significant at the 5 percent level.
** Significantly larger at the 1 percent level than the controls.
[1] 66 days after the first implantation, these animals recieved a second treatment of an additional 60 mg.

significantly depressed in weight. In experiment X this depression was also observed but was not significant. No significant difference was noted between the ovarian weight of the treated heifers and that of the controls. Gross observation, however, showed a marked depression of the number of functional corpora lutea in the treated glands. It is interesting to note that in the one case where a second treatment of 60 mg. was administered to heifers 66 days after the first implantation of 60 mg. there appeared to be a return to a normal weight of the pituitary and adrenal. The thyroids remained depressed. The ovaries weighed less than the controls and contained fewer corpora lutea. None of these weights, however, was significantly different

either from the controls or the singly treated animals. With a larger group these differences could perhaps be clarified.

Effect on Histology. No detectable effects as a result of treatment either by a single implantation or by a second implantation 66 days later could be observed in the gross histological structure of the thyroids in heifers. In steers, on the other hand, as judged by the greater size of the nuclei and the heightened epithelium of the cuboidal cells lining the follicle in the treated glands it would appear that there was some increase in activity. Due, however, to the great variation between glands it is difficult to draw any definite conclusions. Similarly in the pituitaries no gross histological changes were apparent as a result of estrogen treatment in either steers or heifers. A detailed cytological study may prove more fruitful, since in the hypophysis of both the treated heifers and steers there appeared to be a greater number of acidophils than in the controls.

As previously mentioned, the adrenal hypertrophy was due largely to cortical enlargement. Histologically, the adrenal glands of the treated animals were not grossly different from the controls. The increase in the width of the cortex could be accounted for largely by an increase in the width of the glomerulosa as well as the fasciculata. In the beef adrenal gland, trabeculae extend down into the cortex from the capsule, and on either side of these, can be distinguished the glomerulosa. For this reason it is difficult to measure accurately the extent of the enlargement of either the zona glomerulosa or the zona fasciculata.

Microscopic examination of the ovaries confirmed the earlier gross observations that the glands from the treated heifers contained fewer corpora lutea and in many there were large cystic follicles.

Effect on Growth Hormone Content of the Pituitary. Table 10 compares the quantity of growth hormone contained in the anterior pituitary gland of stilbestrol treated heifers and steers with their controls. The amount of hormone present in the glands of the treated heifers was approximately twice that of the untreated control heifers. On the other hand little difference in glandular content was noted between treated and control steers although the amount contained in the treated glands was in every case slightly less than the controls. It is difficult to interpret these results in view of the markedly greater increase in rate of gain obtained by the treated steers over the controls as contrasted to the relatively small increase manifested by the

treated heifers. Since this assay represents only the content of the gland which is not necessarily an indication of secretary rate, the correct interpretation must await further development.

Effect on Adrenocorticotrophin Content. The content of adrenocorticotrophic hormone in the treated steer pituitaries was not significantly different from the glands in the untreated animals as determined by regression of thymus weight in 4-day-old rats. The average thymus weight of the uninjected control recipient rats was 34.4 gm. The thymus weight of those rats receiving pituitary extract from treated

TABLE 10. GROWTH HORMONE ASSAY OF THE PITUITARIES FROM STILBESTROL TREATED AND CONTROL HEIFERS AND STEERS. HYPOPHYSECTOMIZED RATS WERE USED AS THE BIOLOGICAL TEST ANIMAL

Experiment Number	Type of Donor	Total Anterior Lobe Extract Injected per Rat	Number of Rats	Average Increase in Body Weight of Rats Receiving Extract	Increase in Epiphyseal Width Over Untreated Control Rats	Approximate Units[1] of Growth Hormone per gm. of Anterior Lobe	Approximate Units[1] of Growth Hormone per Whole Pituitary
		mg.		gm.	micra		
			Heifers				
I	Control	83	5	2.6	61	15	24
	Treated	79	6	6.8	102	26	47
			Steers				
IV	Control	80	6	4.5	62	15	33
	Treated	80	5	2.4	46	12	31
XI	Control	65	10	8.0	112	35	67[2]
	Treated	65	6	4.3	78	24	55[2]

[1] A unit is equivalent to an increase in width of 50 micra over the untreated control rats.
[2] The difference in extraction procedure (explained in text) may account for the great increase in activity over previous trials.

steers was 17.9 gm. and the thymus weight of those rats receiving an equal quantity of extract from the pituitaries of untreated steers was 17.0 gm.

Effect of Stilbestrol on the Differential Blood Counts in Lambs

Table 11 denotes the effects of stilbestrol treatment on the differential blood cell counts of wether and ewe lambs. The results indicate a marked eosinopenic response following treatment with either 12 or 24 mg. of stilbestrol in both wethers and ewes.

Since a depression of blood eosinophils is related to an increase in adrenal cortical activity stimuated by an increased secretion of ACTH,

it would appear that stilbestrol causes an increased release of this hormone from the ruminant pituitary thus bringing about adrenal cortical stimulation.

TABLE 11. THE EFFECT OF STILBESTROL ON DIFFERENTIAL BLOOD COUNTS IN WETHER AND EWE LAMBS

Type of Animal	Treatment mg.	Percent Agranulocytes	Percent Neutrophils	Percent Eosinophils
Wether	none	81.0	16.0	2.0
"	"	78.6	19.4	2.0
"	"	85.5	12.6	2.4
Average		85.0	16.0	2.1
Wether	12	79.8	19.1	1.0
"	12	75.3	34.2	0.5
Average		77.5	26.7	0.75
Wether	24	63.5	35.4	1.1
"	24	69.4	30.0	0.6
"	24	65.2	34.8	0.0
Average		66.0	33.4	0.6
Ewe	none	68.0	31.0	1.0
"	"	65.6	32.4	2.0
"	"	71.5	26.7	1.8
Average		68.4	30.0	1.6
Ewe	12	68.5	31.5	0.0
"	12	65.5	33.6	0.9
"	12	69.2	30.8	0.0
Average		67.7	32.0	0.3
Ewe	24	78.5	21.5	0.0

Discussion

The spectacular increases in rate of gain with stilbestrol treatment in ruminant animals, particularly in steers, is contradictory to the estrogenic effects in most other species.

Age, sex, castration, and feed intake all contribute to further complications of effect. For instance, Jordan and Dinusson (1949) have reported that gains in very young suckling lambs are not increased by stilbestrol treatment. The effect in the intact female is apparently

complicated by the presence of endogenous estrogens. Either a lack of responsivity or the presence of inhibiting factors may be involved in the failure to produce as great an increase in the rate of gain in the treated heifers as can be shown in treated steers. The amount and type of feed consumed plays a vital role; for in those cases where the higher percentage of intake consisted of roughage little effects of treatment on rate of gain was noted.

The fact that feed consumption is slightly increased but the economy of gain is greatly increased would point to the fact that protein anabolic processes are accelerated. Growth hormone and androgens are both effective in increasing nitrogen retention but our results would indicate that androgen is probably responsible for this effect in cattle and sheep. The results of nitrogen balance trials obtained with steers with and without stilbestrol treatment indicate a greatly increased nitrogen retention. Whitehair *et al.* (1953) report similar increases in nitrogen retention in lambs treated with stilbestrol. That this is an indirect effect mediated by the pituitary is indicated by the occurrence of an androgenic response. The steer carcass has a similar appearance to the intact male. During the course of some of the trials both steers and heifers developed a typical nymphomania stance, i.e., an elevated tail head. Excessive riding was a characteristic behavior during the first few weeks after treatment. The animals behaved in a bull-like manner, i.e., they bellowed, and pawed the ground.

The fact that pituitary gland is hypertrophied, that ACTH secretion is increased as indicated by a depression of blood eosinophils in lambs and hypertrophy of the adrenal gland in both cattle and sheep would indicate that androgens are responsible for the growth effect. The results of Gassner *et al.* (1951), who report the isolation of a fraction with androgenic activity from the adrenal venous blood of cows stimulated with ACTH, helps support this assumption.

Although the pituitary content of growth hormone and ACTH in treated steers was not significantly different from the glands of the untreated steers, the question remains whether the content of the gland by itself is indicative of secretory activity. In heifers the amount of growth hormone in the pituitary is increased; this result is difficult to interpret in view of the fact that the growth response was less in heifers than in steers.

The symptoms of stilbestrol treatment, other than the masculinizing effects are numerous. Some of the treated heifers suffered from prolapse of the vagina which usually occurred in about 8 to 10 weeks

following implantation. In both treated steers and heifers there occurred marked mammary growth. The teats lengthened and the udders underwent considerable development. In a few steers as late as 70 days after treatment some milk was found in the udder at the time of slaughter. When heifers were slaughtered not later than 60 days after implantation their udders contained large amounts of milk. In general all symptoms, both masculinizing and mammary development, had substantially subsided by the end of 90 days following treatment.

Summary

The effects of stilbestrol implants on rate of gain, economy of feed utilization, endocrine weights, growth hormone and ACTH content of the pituitary, endocrine gland histology, nitrogen retention and differential blood counts were studied. Approximately 340 treated animals and a corresponding number of controls were used in these experiments. In different trials the dietary regime was varied such that in some the animals were maintained on irrigated pasture with and without supplements; and in others the animals received hay and concentrates. Treated steers in the feed lot or on pasture with supplemental concentrates made greater gains than controls, or than treated steers on pasture alone. The growth response of treated heifers in the feed lot was in no case as marked as treated steers. On pasture, treated heifers showed no increase in gain over controls. Feed consumption and economy of feed utilization was increased in all treated animals. The growth response in wether and ewe lambs on pasture was greater with a dose of 12 mg. than with 24 mg. of stilbestrol. Nitrogen retention was almost doubled in steers following stilbestrol administration. The weights of the pituitary and adrenal glands were significantly larger in the treated animals. Thyroids of treated steers were larger but not significantly. In treated heifers the thyroid weight was significantly depressed. Ovarian weight was not altered after treatment, but corpora lutea formation was depressed. Growth hormone and ACTH content of treated steer pituitaries was not significantly different from controls. The hypophysis of treated heifers contained twice as much growth hormone as the untreated. Wether and ewe lambs showed a marked eosinopenic response following stilbestrol treatment. The percent of treated animals in the higher carcass grades was less than the percent of untreated. The predominant signs of treatment were masculinization and mammary gland development. Several cases of vaginal prolapse occurred in heifers as a result of

stilbestrol implantation. The role of the pituitary in mediating the growth response to stilbestrol is discussed.

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HISTOCHEMICAL OBSERVATIONS OF THE BOVINE UTERUS, PLACENTA, AND CORPUS LUTEUM DURING EARLY PREGNANCY[1]

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EARLY embryonic death is an important factor in reproductive failures in cattle (Tanabe and Casida, 1948). It was felt that abnormal uterine metabolism might be responsible for a part of these early embryonic deaths and hence the desirability of obtaining a better understanding of normal uterine metabolism during early pregnancy. The cells lining the maternal crypts in the bovine cotyledon during early pregnancy and the binucleate cells of the fetal villi contain abundant stores of alkaline phosphatase (Amoroso, 1952; Weeth, 1953) and some lipid (Weeth, 1953). The alkaline phosphatase and lipids were restudied in an attempt to obtain a better understanding of uterine changes during the early stages of pregnancy.

Experimental Procedure

Tissues were available from the reproductive tracts of 24 yearling Polled Shorthorn heifers, 8 crossbred Angus-Hereford heifers, and 11 dairy cows and heifers. One of the objectives of this investigation was to determine the time and mode of attachment of the embryo to the wall of the uterus and the 43 cows and heifers yielded a total of 26 timed embryos. Twenty-four embroys were between 25 and 47 days of pregnancy while the other two were obtained at 78 and 116 days of gestation.

Tissue samples were taken from the uterine mucosa including both maternal cotyledons and the intercotyledonary areas, and from the fetal chorion. Though the attachment between the fetal and maternal cotyledons is extremely tenuous at these stages of gestation, early placentomes from all tracts, with the 2 tissues still joined together, were dissected and fixed successfully. A tissue sample was taken also from the central area of each corpus luteum of pregnancy. Tissues were

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fixed in Bouin's, cold 80 percent alcohol, and 10 percent neutral formalin. The Bouin's fixed tissues were sectioned at 10 micra after paraffin imbedding and stained with hematoxylin and eosin. Alkaline phosphatase was estimated on the alcohol fixed tissues by the Gomori (1939) method using 3 and 24 hours incubation time. The formalin fixed tissues were embedded in gelatin (Zwemer, 1933), sectioned on a freezing microtome and stained with sudan IV (Herxheimer's solution—Cowdry, 1943) for neutral fats or by the Schultz (1924) technique for cholesterol.

Results

Alkaline Phosphatase

The distribution of the enzyme at 25–47 days of pregnancy was quite general throughout the endometrium. In all areas of all sections, the endothelium of the capillaries and small blood vessels was positive. This was true not only in the upper and middle zones of the cotyledons and intercotyledonary endometrium but when myometrium was present on a section, the black outline of the blood vessels stood out in sharp contrast to the pale background of muscle tissue. The uterine glands contained small amounts of enzyme and, in some cases, the secretory products in the lumina of the glands gave a positive test. The connective tissue of both the cotyledonary and intercotyledonary areas exhibited only a slight reaction except in a narrow zone just below the surface of the cotyledons where there was a more intense concentration of alkaline phosphatase. In the intercotyledonary area, the connective tissue was more open, highly vascular, and just below the surface, the subepithelial connective tissue exhibited a fairly intense phosphatase reaction which faded as it approached the middle of the mucosa. The tissues from the 2 cows slaughtered at 78 and 116 days of pregnancy gave similar reactions.

All samples of chorion from 16 heifers slaughtered between 25 and 45 days of gestation and from the 2 animals slaughtered at 78 and 116 days respectively showed a positive reaction for alkaline phosphatase. The capillaries and smaller blood vessels showed an intense black stain while the nucleated red blood corpuscles contained in them reacted with a black ring around the outer surface and a gray color throughout. The inner face of the allantois and its embryonic connective tissue exhibited a slight reaction with prominent nucleoli and lightly stained cytoplasm. The principal site of alkaline phosphatase in the placenta, however, seemed to be in the cells of the

trophoblast. While the cytoplasm in general was only lightly stained and many of the nuclei exhibited only dark rings around their edges, some of the larger cells and especially the binucleate cells showed nuclei which were stained intensely. After the 36th day the greatest concentrations of alkaline phosphatase appeared consistently in the villi of the developing cotyledons. All section of chorionic tissue from animals slaughtered between 36 and 45 days of pregnancy as well as the 2 animals slaughtered at 78 and 116 days exhibited numerous areas of dense black stain along the surface of the villi (figure 1).

In contrast to the intense reaction of the large round, and binucleate cells, the tall, narrow pseudostratified cells which occur at irregular intervals along the surface of the trophoderm exhibited a very slight reaction (figure 2). The significance and functions, if any, of these limited areas of distinctive cells of the trophoderm are not known. Certainly, from the evidence, they are not closely associated with enzyme activity.

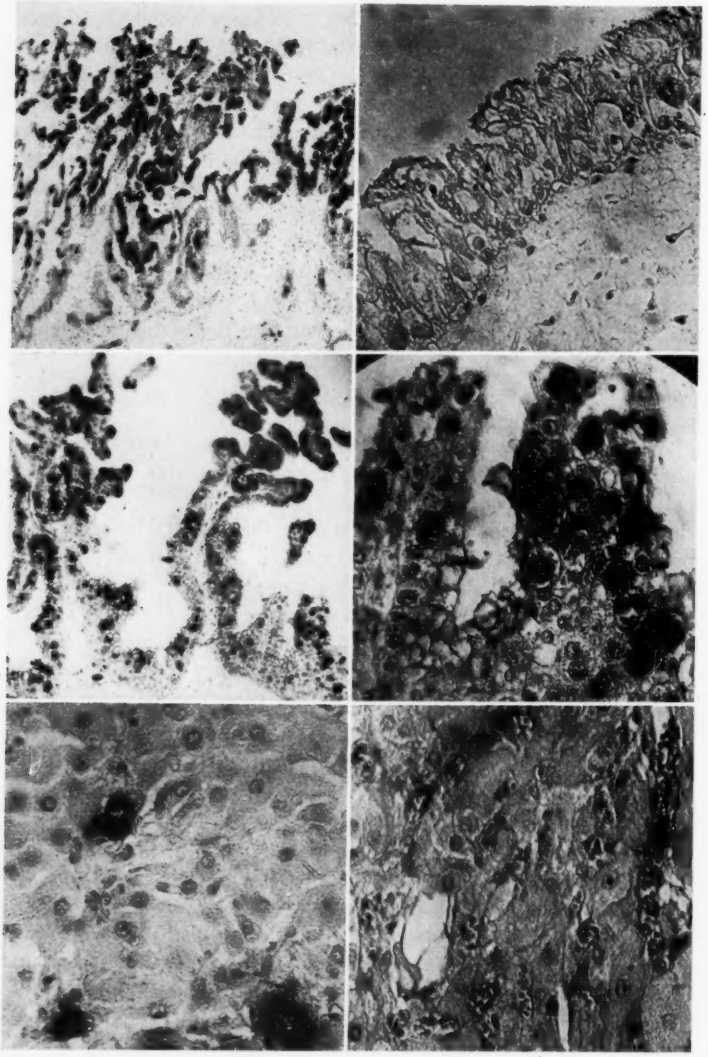
At 116 days of gestation the fetal cotyledons are highly developed and the individual villi are nested in hundreds of crypts in the maternal caruncles. When this fetal tissue was carefully separated from the maternal cotyledons to avoid tearing the delicate branches, and processed by the Gomori (1939) method, excellent sections were obtained. The distribution of alkaline phosphatase at this stage was essentially the same as that described for earlier stages (figures 3 and 4).

All 22 samples of lutein tissue from the corpora lutea of heifers slaughtered between 25 and 45 days of pregnancy contained alkaline phosphatase. The enzyme was present in good concentration in the endothelium of the blood vessels and capillaries. Only moderate amounts, however, were seen in the nuclei and nucleoli, with the cytoplasm essentially negative (figures 5 and 6).

Neutral Fats

When stained with Herxheimer's solution the endometrium of heifers pregnant 25 to 35 days lacked fat. However, the masses of red blood corpuscles in the large blood vessels acquired a yellow tinge which caused them to stand out conspicuously against the background of connective tissue which had been lightly stained with Harris' hematoxylin. In contrast to the endometrium, all tissues from the placenta contained neutral fats, being concentrated largely at the base of the trophoblast cells.

The results with Herxheimer's solution for the 22 samples of tissue



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ALKALINE PHOSPHATASE CONTENT OF CHORION AND CORPUS LUTEUM

Figure 1. Though lightly stained, this view of intervillous trophoderm at 78 days shows a slightly greater content of alkaline phosphatase in the nuclei of the large cells at the left and right than in the pseudostratified cells in the center. (x 600)

Figure 2. At 78 days, alkaline phosphatase is distributed abundantly in this fetal cotyledon. (x 50)

Figure 3. At 116 days, the distribution of alkaline phosphatase is essentially the same as at 78 days. (x 100)

Figure 4. This high-power view of the two small villi at the right in Figure 3 shows clearly the staining of the individual cells by the Gomori technique. Note intense reaction of binucleate cells. (x 600)

Figure 5. Note intense concentration of alkaline phosphatase in the endothelium of the blood vessels and distinct rings around the nuclei with prominent nucleoli in these lutein cells at 26 days. (x 600)

Figure 6. Increased vascularity is evident at 37 days in this corpus luteum. Note reaction of the erythrocytes for alkaline phosphatase. (x 600)

from corpora lutea of cattle between 25 and 45 days of pregnancy were inconclusive and somewhat puzzling. Fat staining occurred in the cytoplasm in some but not all of the lutein cells of a given section.

Cholesterol

All samples of endometrium and chorion gave positive reactions to the Schultz (1924) test for cholesterol (table1). While, in general, the tissues from the intercotyledonary area reacted more strongly than those from the maternal cotyledons, there was considerable variation among the individual sections. Some tissues exhibited a strong blue-green color reaction almost immediately, while others went through a prolonged violet stage. The area and the extent of the color changes

TABLE 1. CHOLESTEROL CONTENT OF ENDOMETRIUM AND CHORION

No. of Samples	Pregnant (Days)	Maternal Cotyledons [1]	Inter-cotyledonary Area [1]	Chorion [1]
5	25–26	*	**	**
4	27–30	**	***	**
6	33–36	***	**	**
5	37–39	**	***	***
3	42–47	**	***	**

[1] Slight reaction *, Medium reaction **, Strong reaction ***.

were also quite varied and it was not possible to localize the reaction in the mucosa or the placenta. However, when villi were present in the sections of chorion from animals slaughtered during the 2nd month of pregnancy, there was a very definite color reaction at their growing tips.

Discussion

The limited use of histochemical methods in this experiment, for studying tissues from the reproductive tract of the cow, was successful in providing additional data which were generally in agreement with results obtained by other investigators. The intense concentration of alkaline phosphatase in the endothelium of the blood vessels, its distribution throughout the endometrium of the uterus and the lutein cells of the corpus luteum and its abundance in the binucleate cells of the chorion were noted. Its specific functions in these tissues and organs, however, are still unknown. This investigation likewise yielded no specific answers relative to the role of the pseudostratified cells of the trophoderm but it would be interesting to follow up with further work the phagocytic function assigned to them by Jenkinson (1913).

The presence of large quantities of neutral fats in the trophoderm as demonstrated by Herxheimer's solution suggests a possible relationship to the production of placental steroid hormones. Perhaps, too, in this connection we may need to revise our thinking relative to the role of lipids in the nourishment of the embyro.

Summary

Alkaline phosphatase as determined by the Gomori (1939) method was present in substantial amounts in the endometrium, chorion, and corpus luteum during the *early months* of pregnancy in the bovine. The enzyme was present in the endothelium of the uterine blood vessels, in the uterine glands and their secretions and just below the surface of the endometrium in both the cotyledons and in the intercotyledonary area. All samples of chorionic tissue were positive for alkaline phosphatase, the principal site of the enzyme being in the larger cells and especially the binucleate cells of the trophoblast and the fetal villi. The corpora lutea of pregnancy were positive for alkaline phosphatase with a medium reaction of the nuclei and cytoplasm of the lutein cells and an intense staining of the endothelium of the blood vessels. The reaction of the cells lining the maternal crypts to the test

for alkaline phosphatase was identical with that of many cells in the fetal villi.

Neutral fats could not be demonstrated in the endometrium of heifers pregnant 25 to 35 days. All sections of chorion, however, gave a positive reaction especially at the base of the trophoblastic cells. Corpora lutea provided inconclusive results for neutral fats.

All sections of maternal endometrium, both cotyledons and the intercotyledonary area, gave a positive reaction to the Schultz (1924) test for cholesterol as well as all samples of chorion which were tested.

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ESTROGENIC ACTIVITY OF THE MEAT OF CATTLE, SHEEP AND POULTRY FOLLOWING TREATMENT WITH SYNTHETIC ESTROGENS AND PROGESTERONE [1]

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THE accumulation of knowledge during the past two decades concerning the structure and synthesis of a wide variety of estrogens has led to many investigations dealing with the physiology and therapeutic uses of these hormones. Of practical importance to the animal husbandman has been the increased rate of gain and improved feed efficiency in cattle, sheep and poultry following treatment with hormones, particularly the synthetic estrogen, diethylstilbestrol. The use of synthetic estrogens would be of no value, however, if there were sufficient amounts of hormone retained in the tissues of treated animals to constitute a hazard to humans ingesting the meat of these animals. The purpose of this investigation was to determine the estrogenic hormone activity of the muscle tissues and liver of estrogen-treated cattle, sheep and chickens. Since the method of human exposure would be *per os*, and since it has been demonstrated that extremely small quantities of estrogens can be detected upon oral administration in ovariectomized mice, it was decided to use an assay technique including these characteristics.

Materials and Methods

Meat of three species of animals was assayed for residual hormone activity. Beef was obtained from steers slaughtered 140 days after estrogen treatment. Lamb muscle was secured from wethers slaughtered 4, 8, 10 and 12 weeks after treatment. Chickens were sacrificed for assay 1, 2, 3 and 4 weeks following the implantation of a 12mg. pellet of stilbestrol subcutaneously. Usually the beef or lamb assayed was neck trim consisting of approximately 70% lean and 30% fat; in some trials the entire fore leg was ground and assayed. In chickens the entire edible carcass was assayed.

The meat, both muscle and liver, was ground to a hamburger-like fineness and air dried. A commercial chicken mash used as the stock ration for mice was added to the ground meat in proportion by weight of 1 part mash to 5 parts ground dried meat. This meat-mash mixture

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was fed to castrated, female mice of the Rockland-Swiss strain for a 10-day period. The mice were sacrificed on the eleventh day, i.e. 24 hours after the last feeding. At autopsy the uteri were removed and weighed on a torsion balance. The presence of residual hormone was detected by differences in the average uterine weights of animals fed control meat in comparison to those fed meat from animals treated with estrogens. The assay procedures used have been published in detail elsewhere (Stob *et al.*, 1953).

Results

Beef Muscle, Experiment 1

Assays of neck meat were made of composite samples obtained from four groups of steers. Each composite sample contained the meat of five steers. As shown in table 1, the steers had been treated with either

TABLE 1. ASSAY OF BEEF MUSCLE. EXPERIMENT 1.

Group	Steer Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	8	33.50	24.35	.074
2	60 mg. stilbestrol	9	29.66	24.86	.084
3	120 mg. stilbestrol	10	30.10	29.94*	.099**
4	80 mg. dienestrol	10	29.80	24.00	.080

* $P<0.05$.
** $P<0.01$.

stilbestrol or dienestrol pellets implanted subcutaneously in the neck 140 days prior to slaughter. Uterine weights of the test mice were not significantly affected by the meat of the steers which received 60 mg. of stilbestrol or 80 mg. of dienestrol. The meat of steers treated with 120 mg. of stilbestrol did increase uterine weight ($P<0.05$).

Beef Liver, Experiment 1

Composite liver samples from eight groups of steers were assayed as summarized in table 2. Each sample contained the livers of 5 steers and two of these composite samples from each treatment were assayed. For purposes of statistical analysis, group 1 served as the control for groups

2, 3 and 4, and group 5 was the control for the last three groups. The liver samples from both groups of dienestrol-treated steers increased uterine weight ($P<0.05$). In all other groups of mice the liver tended to increase uterine weight but these differences were statistically significant in only one lot of liver. When uterine weight was expressed as a percent of body weight, two other groups were significantly heavier than the controls.

In this trial there was apparently no correlation between the amount of hormone used and the retention in the meat. There is an indication however, that the type of hormone used may have had an effect with

TABLE 2. ASSAY OF BEEF LIVER. EXPERIMENT 1.

Group	Steer Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	9	27.44	19.93	.073
5		9	26.33	21.28	.081
2	60 mg.	9	26.33	22.20	.084*
6	stilbestrol	10	27.70	24.14*	.088
3	120 mg.	8	25.87	22.02	.084**
7	stilbestrol	10	29.10	24.44	.083
4	80 mg.	10	27.50	23.98*	.087**
8	dienestrol	8	27.25	25.67*	.095

* $P<0.05$.
** $P<0.01$.

respect to residual hormone in beef liver, i.e., in both groups fed liver from dienestrol-treated cattle the uterine weights were most consistently affected.

Addition of Stilbestrol to Beef Muscle

In order to check the assay procedures further it was decided to add known amounts of stilbestrol to meat samples from non-treated steers. The hormone was added both before and after drying. Meat from the steers treated with 120 mg. of stilbestrol (group 3, table 1) was again assayed as a positive control. The data presented in table 3 indicate that stilbestrol does not lose its activity when added to meat and dried. The difference in uterine weights between groups 1 (control) and 2 (hormone implanted) was not significant but a four milligram increase indicates some hormonal activity of the meat.

TABLE 3. ASSAY OF BEEF MUSCLE TO WHICH KNOWN AMOUNTS OF DIETHYLSTILBESTROL WERE ADDED BEFORE AND AFTER DRYING. REPETITION OF ASSAY OF BEEF MUSCLE, EXPERIMENT 1, GROUPS 1 AND 3.

Group	Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	10	29.20	23.78	.082
2	120 mg. stilbestrol steer group 3	10	28.20	27.52	.098
3	.022 ug. stilbestrol before drying	10	28.40	32.44**	.115**
4	.025 ug. stilbestrol after drying	10	30.50	36.14**	.121**

** $P<0.01$.

Beef Muscle, Experiment 2

The meat assayed in this experiment was from steers slaughtered 140 days after hormone treatment. Composite samples were again used; the results are presented in table 4. Treatment with 108 mg. of stilbestrol

TABLE 4. ASSAY OF BEEF MUSCLE. EXPERIMENT 2.

Group	Steer Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	10	24.00	11.26	.045
5		8	22.50	13.82	.061
2	108 mg.	9	24.00	15.44**	.059*
6	stilbestrol	10	28.10	21.48**	.076*
3	60 mg. stilbestrol	10	24.10	11.60	.048
7	200 mg. progesterone	9	28.60	22.86**	.080**
4	120 mg. dienestrol	6	25.50	20.13**	.079*
8	300 mg. progesterone	10	27.10	19.70*	.072
9	grain	10	25.10	23.35	.093
10	grain plus casein	8	25.10	20.02	.091

* $P<0.05$.
** $P<0.01$.

or 120 mg. dienestrol and 300 mg. progesterone consistently produced estrogenic activity in the meat.

The observation had been made that the uterine weights of mice fed a meat-mash mixture were heavier than those fed a straight grain (mash) ration. Since this might have been attributed to differences in protein levels, the 20% protein grain ration was increased to 35% (approximately that of the meat-mash mixture) by the addition of commercial casein. The data in table 4, groups 9 and 10, indicate that protein as such does not affect uterine weight. It should be observed that the all grain ration fed the mice in group 9 produced the heaviest uterine weights of any group. Estrogenic activity normally present in grain rations may be greater than in the meat of steers treated with hormones.

Effect of Cooking the Meat of Hormone-Treated Steers. The Effect of Heat on Stilbestrol.

The most common means by which man would be exposed to the meat of hormone treated animals would be through the ingestion of cooked meat. For this reason, meat known to have residual hormone activity and meat to which known amounts of hormone were added was cooked in 1000 gram meat loaves in an oven at 120 to 150° C. for 2 hours. Test animals were fed this cooked meat without a grain diluent for the usual 10-day period. The data presented in table 5 indicate that cooking *per se* had no effect on estrogen activity. This is not surprising because stilbestrol is very heat stable and has a melting point of 167 to 168° C. A loss of activity could occur in the tissue juices and rendered fat which were discarded in this case.

Lamb Muscle, Experiment 1

The meat assayed in this trial was neck meat obtained from lambs slaughtered seventy days after treatment with 12 mg. of stilbestrol; a composite sample of meat from 25 lambs was assayed. The control meat was a composite sample obtained from 10 non-treated lambs. The same procedures were used in the drying of the lamb as were described for beef. As shown in table 6, the feeding of hormone-treated lamb meat increased uterine weight of castrated female mice significantly. This is not surprising since the 108 mg. level of stilbestrol in steers caused a significant increase in uterine weight in test mice. This level of hormone (108 mg.) in a 700-pound steer is approximately equivalent on a relative weight basis to 12 mg. in an 80-pound lamb.

TABLE 5. EFFECT OF COOKING ON MEAT KNOWN TO HAVE HORMONAL ACTIVITY AND MEAT TO WHICH KNOWN AMOUNTS OF HORMONE HAVE BEEN ADDED

Group	Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	12	27.00	14.72	.066
2	.025 ug. stilbestrol per gram raw meat	11	22.09	39.07**	.178**
3	.100 ug. stilbestrol per gram raw meat	10	23.50	116.34**	.495**
4	120 mg. dienestrol 300 mg. progesterone	10	24.40	18.72**	.077*

* $P<0.05$.
** $P<0.01$.

Lamb Liver, Experiment 1

The liver assayed in this trial was taken from the same group of lambs described above. In contrast to all the other feeding trials, the lamb liver was fed only for a seven-day period because of the limited liver available from the control lambs. The data in table 7 indicate that, in contrast to beef liver, there is no residual hormone activity in stilbestrol-treated lamb liver.

Lamb Muscle, Experiment 2

The purpose of this study was to determine the effect of time, amount of hormone and site of implantation on residual estrogen. Lambs treated

TABLE 6. ASSAY OF LAMB MUSCLE. EXPERIMENT 1.

Group	Lamb Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	10	28.10	22.56	.081
2	12 mg. stilbestrol	10	32.10	32.64*	.104

* $P<0.05$.

TABLE 7. ASSAY OF LAMB LIVER. EXPERIMENT 1.

Group	Lamb Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	10	24.50	21.04	.086
2	12 mg. stilbestrol	10	26.10	21.96	.084

with 12 mg. of stilbestrol implanted subcutaneously in the neck, ear or scrotum or 24 mg. in neck and ear were killed 4, 8 and 12 weeks after treatment. One lamb from each treatment was killed at each time interval. The results of this trial are presented in tables 8, 9 and 10. It will be observed that the treatment with 12 mg. of stilbestrol resulted in detectable residual estrogen in only one case and that occurred 12 weeks after hormone treatment. This is in contrast to the results of the first assay of lamb muscle in which detectable amounts were present 70 days after treatment with the same level of hormone. Doubling the hormone dosage to 24 mg. resulted in marked estrogen retention except for the 8-week interval. The data in table 9 indicates the desirability

TABLE 8. ASSAY OF LAMB MUSCLE. EXPERIMENT 2. FOUR WEEKS AFTER HORMONE TREATMENT.

Group	Lamb Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	10	26.20	16.47	.063
2	12 mg. stilbestrol in the neck	10	26.30	18.98	.072
3	12 mg. stilbestrol in the ear	9	28.78	17.16	.060
4	12 mg. stilbestrol in the scrotum	10	24.90	17.34	.069
5	24 mg. stilbestrol in the neck	9	21.11	85.11**	.358**
6	24 mg. stilbestrol in the ear	9	26.89	150.36**	.562**

** $P<0.01$.

TABLE 9. ASSAY OF LAMB MUSCLE. EXPERIMENT 2. EIGHT WEEKS AFTER TREATMENT.

Group	Lamb Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	9	29.22	15.73	.053
2	12 mg. stilbestrol in the neck	10	26.30	15.64	.059
3	12 mg. stilbestrol in the ear	9	28.22	14.98	.053
4	12 mg. stilbestrol in the scrotum	10	28.30	9.42	.033
5	24 mg. stilbestrol in the neck	8	26.38	12.75	.048
6	24 mg. stilbestrol in the ear	10	28.70	13.08	.050

TABLE 10. ASSAY OF LAMB MUSCLE. EXPERIMENT 2. TWELVE WEEKS AFTER HORMONE TREATMENT.

Group	Lamb Treatment	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight mg.	% Body Weight
1	control	9	27.89	15.02	.054
2	12 mg. stilbestrol in the neck	9	28.00	14.69	.053
3	12 mg. stilbestrol in the ear	9	29.78	13.33	.044
4	12 mg. stilbestrol in the scrotum	10	28.22	18.49**	.066
5	24 mg. stilbestrol in the neck	9	25.22	125.90**	.507**
6	24 mg. stilbestrol in the ear	10	24.10	97.52**	.403**

** $P<0.01$.

of a composite meat sample rather than one from individual animals. An explanation for the lack of estrogen activity at this time is the encapsulation of the pellet with a resultant failure of relase of hormone into the circulation. True, it would be coincidental that this would happen in both lambs treated with 24 mg. of stilbestrol at this time. If this were the case the sampling of greater numbers of animals would probably eliminate this type of experimental error. The data presented in table 11 demonstrate that there was only a slight loss of residual

TABLE 11. ASSAY OF LAMB MUSCLE. SUMMARY OF ALL DATA IN EXPERIMENT 2.

Treatment	No. of Mice	Mean Uterine Weight—mg. St'd. Error	Time After Hormone Treatment
Control	10	16.47±1.09	
12 mg. stilbestrol	29	17.85± .68	4 weeks
24 mg. stilbestrol	18	117.83±9.62	
Control	9	15.73±1.77	
12 mg. stilbestrol	29	13.30± .76	8 weeks
24 mg. stilbestrol	18	12.93± .79	
Control	9	15.02± .87	
12 mg. stilbestrol	27	15.50± .64	12 weeks
24 mg. stilbestrol	19	110.96± .31	

estrogenic activity in lamb meat from the 4th to the 12th weeks following treatment.

Assay of Chicken Carcasses

Fifteen eight-week-old Barred Rock cockerels were each implanted subcutaneously in the neck region with a 12 mg. pellet of stilbestrol. Fourteen untreated cockerels served as controls. Treated and control birds were sacrificed 1, 2, 3 and 4 weeks after stilbestrol implantation. For assay purposes a composite sample of two or three birds was used at each sampling interval. In each case, pellet residues were recovered and weighed. Treated birds which did not show evidence of estrogen treatment, i.e. pale and atrophic combs were not used. The birds were eviscerated, the head and feet removed and the entire carcass run through a food chopper.

TABLE 12. ASSAY OF MEAT OBTAINED FROM CHICKENS TREATED WITH 12 MG. STILBESTROL SUBCUTANEOUSLY. EFFECT OF TIME ON RESIDUAL HORMONE ACTIVITY.

Treatment	Time After Pellet Implantation Weeks	No. of Mice	Mean Body Weight gm.	Mean Uterine Weight—mg. St'd. Error	% Body Weight
Control	1	10	24.50	21.86±1.67	.088
Treated		10	25.80	105.14±8.03	.408
Control	2	10	26.70	18.32±1.03	.069
Treated		10	25.60	40.78±4.61	.158
Control	3	10	26.90	14.48± .85	.054
Treated		10	26.10	55.70±6.71	.215
Control	4	10	26.00	12.64± .76	.049
Treated		10	27.40	28.36±2.07	.103

The results are presented in table 12. Treatment with 12 mg. of stilbestrol resulted in considerable hormone retention. It must be remembered on a dose per unit of body weight basis this is a rather high level of hormone in comparison with sheep and cattle. However, this is the level used in commercial poultry practice. In contrast to sheep there was a marked reduction in residual estrogen with time. Since pellet residues were present in the treated birds there is a possibility that the estrogenic activity measured was due to circulating or free hormone present in the tissues. Average weights of the pellet residue recovered from the treated birds are presented in table 13.

Discussion

It is well known that age, strain of test animal, level of thyroid activity, adrenal activity and the interval following castration all in-

TABLE 13. RATE OF ABSORPTION OF STILBESTROL PELLETS IMPLANTED SUBCUTANEOUSLY IN THE NECK OF CHICKENS.

Time After Implantation	Mean Weight of Residual Pellet mg.	Total Amount Absorbed mg.	Mean Daily Amount Absorbed ug.
1 week	10.7	3.4	486
2 weeks	8.0	5.6	400
3 weeks	9.9	4.1	195
4 weeks	7.1	6.3	225

fluence uterine weight. In order to minimize experimental variation, the test animals used were of a highly inbred strain, castrated at approximately the same age and were used for assay 4 to 6 weeks following ovariectomy. In addition, control animals were used for each assay. It was assumed, therefore, that significant increases in uterine weights over controls for *any particular assay* was due to residual estrogen even though variation from assay to assay was considerable.

One may conclude that since the largest uterine weights obtained in mice eating beef muscle or liver was 29.94 mg. (table 1) the residual

TABLE 14. AMOUNT (ESTIMATED) OF RESIDUAL ESTROGEN IN THE MEAT OF HORMONE-TREATED ANIMALS.

Type of Meat	Time Interval Between Hormone Treatment and Slaughter	Residual Estrogen ug./gm. Dried Tissue
Beef muscle	140 days	.01
Beef liver	140 days	.01
Lamb muscle	70 days	.01
Lamb muscle	28 days	.1
Lamb muscle	56 days	.01
Lamb muscle	84 days	.1
Chicken muscle	7 days	.05
Chicken muscle	28 days	.01

estrogen would not exceed 0.01 ug. per gram of dried tissue. Previous work in this laboratory demonstrated that when 0.01 ug. of stilbestrol was incorporated into 1 gram of mash and fed to mice that the resulting uterine weights averaged 51.42 mg. The heaviest uterine weights obtained in any sheep muscle assay were 150.36 mg. (table 8) and chicken muscle 105.14 mg. (table 12). Since previous studies have shown that when 0.1 ug. of stilbestrol is added to 1 gram of mash the resulting uterine weights will average 160.37 mg., it was assumed that with respect to lamb and chicken, residual hormone activity does not exceed 0.1 ug. per gram of dried tissue (Stob *et al.*, 1953). Estimated amounts of hormone present in the meat of estrogen treated animals are presented in table 14. These estimates would apply only to the conditions of these experiments.

Qualitatively the results of this paper agree in part with the work of Bird *et al.* (1947) and Gowe (1949) who were able to detect residual estrogens in fowl treated with hormones. In addition, evidence has been

presented that estrogenic residues are present in the tissue of cattle and sheep treated with stilbestrol and dienestrol. This is in contrast to the work of Braude (1950) who reported that the meat of swine treated with stilbestrol orally did not possess any estrogenic activity.

It is not within the scope of this paper to attempt to determine safe tolerance or exposure levels of any hormone for man. If, as the data indicate, the amount of estrogenic (stilbestrol) activity per gram of dried lamb, beef or chicken tissue does not exceed 0.1 ug. and if there is a 50% weight loss in cooking the fresh meat, the cooked meat would contain approximately 0.1 ug. of estrogen. At this level approximately 22 pounds of cooked meat would be required to furnish 1 mg. of stilbestrol per day, which may be considered a typical therapeutic dose for man (U. S. Dispensatory, 1947).

The human tolerance to stilbestrol appears to be extremely high. Ferguson (1953) reported that treatment of 190 pregnant women with a total dose of 11,725.7 mg. of hormone from the 10th to the 30th week of pregnancy had no harmful effects on fetal weight or survival or toxicity to the mother. Under this regime, as much as 137.5 mg. of hormone was taken per day during the 30th week. A person would have to consume 3,028 pounds of meat containing 0.1 ug. of hormone per gram of cooked meat to receive an equivalent amount.

It has been shown by Kirgis and Rothchild (1952) that the implantation of a 25 mg. estradiol pellet into the mesentery of ovariectomized women elicited very little vaginal cornification. Bird *et al.* (1947) reported that women ingesting 8 chicken livers containing approximately 2.0 mg. of the dimethyl ether of diethylstilbestrol daily for 6 days did show a positive vaginal response but the ingestion of a similar level of dienestrol diacetate produced only a slight vaginal secretion. Greenblatt and Brown (1952) were able to recover residual estrogens in women only after the administration of up to 1,152 mg. of a synthetic estrogen Tri-p- anisyl-chloroethylene. These levels are considerably higher than what would be encountered in the consuming of a reasonable amount of meat from hormone-treated animals.

Estrogens do occur in natural foodstuffs. Cheng *et al.* (1952) reported the presence of estrogen in clover and alfalfa hay. They are present in the subterranean clovers of Australia (Curnow, 1948). Schoop and Klette (1952) were able to extract 2 grams of estrogenic material from pasture grasses. In this report, it has been pointed out that an all grain ration elicited a greater uterine response than the ingestion of meat from hormone treated animals (table 4). One of us (Zarrow)

has extracted the equivalent of 3.75 ug. of estradiol/kg. of food from a commercial laboratory ration. Walker and Janney (1930) reported that estrogens were present in oats and rhubarb leaves. Frank (1930) estimated that a medium size potato contained 2 mouse units (0.16 to 0.24 ug.) of female sex hormone. Marlow and Rickert (1940) were able to extract 5 rat units of estrogen from 1 kilogram of egg yolk.

Lorenz (cited in Sykes *et al.*, 1952) reported that beef liver obtained commercially contained as much estrogen as carcasses from diethylstilbestrol treated chickens. It is not unreasonable to assume that cows slaughtered in estrus or during pregnancy would yield carcasses containing estrogen. Mandl (1951) has shown that the adrenal produces estrogens. It has been reported that the testis (Beall, 1940) as well as the ovary is a source of estrogen in the body. On the basis of these last cited references, it would not be at all surprising if estrogens would be detectable in carcasses of non estrogen-treated animals.

Summary

Residual estrogens have been demonstrated in the meat of steers, wethers and chickens treated with synthetic estrogens.

The muscle and liver of steers has been shown to contain residual estrogen but in the case of sheep only muscle showed detectable estrogenic activity.

There was no demonstrable effect of site of hormone implantation on the amount of hormone retained in the edible tissue.

The species differences noted in the amount of residual hormone present are probably a function of time lapse after treatment of the animals with the estrogens.

In poultry, the amount of hormone present was reduced quite markedly with time after hormone treatment. In sheep this loss of activity with time was slight.

Generally speaking, the greater the amount of hormone used in treating the animals, the greater the amount retained.

There was no consistent evidence to indicate that the type of hormone used affected residual amounts in muscle tissue.

The only effect of cooking on residual estrogen was a possible loss of amount of activity in the rendered fat or tissue juices but heat (120 to 150° C. for two hours) *per se* had no effect on the hormone.

In all probability, the amount of hormone present in beef muscle and liver does not exceed 0.01 ug. per gram of dried tissue and 0.1 ug. per gram of dried tissue in the case of sheep muscle and chicken meat.

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THE COMPOSITION OF FOREIGN AND DOMESTIC BONE MEALS USED IN LIVESTOCK FEEDING [1, 5]

T. H. Blosser,[2] W. H. Abbitt,[3] A. O. Shaw,[2] U. S. Ashworth,[2] and E. P. Smith [4]

State College of Washington

BONE meal is one of the most widely used mineral supplements in livestock feeding. It is used principally as a source of calcium and phosphorus. Morrison (1948) lists the calcium and phosphorus content of steamed bone meal as 31.7 percent and 15.0 percent, respectively. One might expect bone meal, being of animal origin, to be a rather complex mineral mixture. Certainly the amounts of the various minerals present might be expected to be in more nutritionally desirable proportions than is true of many mineral feeds now on the market.

The purpose of the experiment reported herein was to study the composition of a number of samples of bone meal available for feeding purposes.

Experimental Procedure

Twenty-two samples of bone meal, 14 of which were of foreign origin, were collected for use in this study. All of the samples were being sold as bone meal; however, after examining the labels it appeared likely that other materials were also present in a few samples. Most of the samples were collected from wholesale and retail feed dealers in the state of Washington. A few samples, however, were obtained from firms which manufacture bone meal outside the state for feeding purposes.

Information concerning the samples analyzed is presented in table 1. Brand names have been omitted, but any descriptive information concerning origin or guaranteed analysis is presented. It is apparent from this table that complete information was lacking on some of the samples. All, however, were being offered for sale as feeding grade steamed bone meal.

Dry matter, ash, ether extract, protein, calcium, phosphorus, magnesium and sulfur were all determined in accordance with methods de-

[1] Scientific Paper No. 1245, Washington Agricultural Experiment Stations, Pullman, Project No. 787.

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[3] Division of Industrial Research.

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[5] The support of Consolidated Chemical Industries, Inc., 111 Sutter Street, San Francisco, California, is gratefully acknowledged.

scribed in the Official Methods of Analysis of the Association of Official Agricultural Chemists (1945).

All remaining constituents were determined spectrographically. Samples submitted were ground and ashed overnight at 600° C. The concentrations of manganese, iron, copper, zinc and fluorine were obtained

TABLE 1. SOURCE AND DESCRIPTION OF BONE MEAL SAMPLES ANALYZED

	Description	
Sample No.	Foreign or Domestic	Description on Label
1	Domestic	5% protein, 30% calcium, 14% phosphorus
2	China	5.25% protein, 63.47% bone-phos-lime [1]
3	Domestic	30% calcium, 14% phosphorus
4	Domestic	30% calcium, 14% phosphorus
5	England	
6	France	4.63% protein, 68.5% bone-phos-lime
7	South America	23% protein, 24% calcium, 10% phosphorus
8	Foreign (source unknown)	
9	Europe	
10	England	
11	Domestic	
12	England	
13	Domestic	5% protein, 30% calcium, 12% phosphorus
14	England	5% protein, 31.31% calcium, 14% phosphorus
15	Domestic	70% bone-phos-lime
16	Domestic	
17	Argentina	
18	Belgium	
19	Italy	
20	Europe	
21	Domestic	
22	England	

[1] A term applied to bone meal to indicate tri-calcium phosphate equivalent. The value is arrived at by multiplying the phosphorus content of bone meal by five.

from conventional working curves. However, the concentrations of all other elements were obtained by the method of visual bracketing between spectra of standard powders of known concentration.

For the fluorine determinations the samples were ashed with three times their weight of fluorine-free oxide. This was done in order to fix the fluorine and to provide the necessary amount of calcium for fluorine determinations with the calcium fluoride band at 5291^{A}. About 80 mg. of the sample were placed in a carbon electrode and the charge partially consumed for 45 seconds by an arc of 310 volts, 5 amperes.

For all elements, except fluorine, 5 mg. samples were burned to completion at 350 volts, 9 amperes. Light from the arc was received by two spectrographs, one a large Bausch and Lomb Littrow spectrograph with quartz optics, the other a two-meter Allied Research Laboratories grating spectrograph with a 36000-lines-per-inch grating.

Results

The results of analysis for the major constituents of bone meal are presented in table 2. The average levels of the major constituents were very similar to those reported for bone meal by Morrison (1948). Individual samples of bone meal from various sources differed quite widely, even in gross composition. The ranges in protein from 0.13 to 25.4 percent, in fat from 0.02 to 9.29 percent, and in sulfur from 0.07 to 7.27 percent were particularly noteworthy. The amounts of calcium and phosphorus were even quite variable and point toward the importance of buying bone meal on a composition guarantee.

Morrison (1948) lists raw bone meal as containing 0.17 percent sulfur and 0.24 percent magnesium. Steamed bone meal samples analyzed in this study contained 1.43 percent sulfur and 0.57 percent magnesium. The marked difference in sulfur content between the figure listed by Morrison (1948) and that found in this study was due principally to four samples which may not have represented pure bone meal as indicated by this and other aspects of their composition.

The average levels of the minor constituents in bone meal, including the trace minerals, are presented in table 3. All elements listed in this table were determined spectrographically. Copper, zinc, iron, fluorine and manganese were determined quantitatively as described previously. Other minerals reported were determined semi-quantitatively.

Little information is available on the trace mineral content of bone meal. Thus it is difficult to determine if amounts of trace minerals found in this study are typical of amounts usually found in bone meal. As pointed out before, spectrographic sensitivity for the various elements differed. With the procedures employed, no cobalt could be detected. Since the procedures measured down to 10 ppm, it is apparent that levels of cobalt in the material analyzed were less than 10 ppm.

Morrison (1948) reports the iron content of raw bone meal as 0.08 percent. No figures are reported for the manganese or copper content of bone meal, but the content of these materials in an animal product such as tankage is 10.0 mg. manganese per pound and 19.8 mg. copper per pound. Expressed in the same way, the average iron content of the

TABLE 2. PERCENTAGE OF SOME OF THE MAJOR CONSTITUENTS IN BONE MEAL

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Sample No.	Dry Matter	Protein	Ether Extract	Ash	Calcium	Phosphorus	Magnesium	Sulfur
	%	%	%	%	%	%	%	%
1	96.87	5.88	.09	84.29	31.14	14.69	1.15	.18
2	95.33	8.09	.22	80.37	28.98	13.35	.71	.11
3	92.54	5.43	.02	82.64	29.77	14.32	.76	.17
4	92.01	5.07	.04	82.48	29.31	14.35	.60	.16
5	97.23	5.27	.15	85.05	31.42	14.78	.73	.20
6	94.44	3.24	.02	87.45	31.11	14.89	.69	.34
7	91.88	25.40	.66	61.22	22.74	10.67	.55	.12
8	93.22	.28	.25	84.06	22.29	13.74	.29	7.05
9	98.18	.13	.34	88.70	24.97	15.36	.24	7.27
10	97.18	.13	.35	89.01	25.67	16.13	.15	6.17
11	97.44	3.11	.15	88.26	32.01	16.35	.12	.20
12	97.24	6.86	.52	84.07	30.34	15.39	.11	.17
13	97.54	9.59	9.29	72.61	31.00	13.44	.85	.12
14	97.15	6.48	.44	83.30	35.53	15.54	.76	.20
15	98.68	.40	.30	86.36	27.98	11.16	.42	7.00
16	97.02	7.92	.29	80.97	33.53	11.48	.54	.20
17	96.87	12.35	.73	77.39	33.35	12.46	.37	.08
18	96.90	8.61	1.44	77.35	31.51	11.41	.51	.47
19	96.72	6.45	.24	82.42	34.49	12.31	.65	.88
20	98.24	3.40	.20	85.48	35.99	13.83	1.04	.07
21	96.56	6.39	.42	83.42	32.90	13.63	.64	.12
22	97.18	7.15	1.77	80.81	35.34	14.33	.71	.22
Mean All samples	96.20	6.26	0.82	82.17	30.62	13.80	0.57	1.43
Mean Excluding samples 8, 9, 10 and 15	96.06	7.59	0.93	81.09	31.70	13.73	0.64	0.22

has extracted the equivalent of 3.75 ug. of estradiol/kg. of food from a commercial laboratory ration. Walker and Janney (1930) reported that estrogens were present in oats and rhubarb leaves. Frank (1930) estimated that a medium size potato contained 2 mouse units (0.16 to 0.24 ug.) of female sex hormone. Marlow and Rickert (1940) were able to extract 5 rat units of estrogen from 1 kilogram of egg yolk.

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6	France	4.63% protein, 68.5% bone-phos-lime
7	South America	23% protein, 24% calcium, 10% phosphorus
8	Foreign (source unknown)	
9	Europe	
10	England	
11	Domestic	
12	England	
13	Domestic	5% protein, 30% calcium, 12% phosphorus
14	England	5% protein, 31.31% calcium, 14% phosphorus
15	Domestic	70% bone-phos-lime
16	Domestic	
17	Argentina	
18	Belgium	
19	Italy	
20	Europe	
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For all elements, except fluorine, 5 mg. samples were burned to completion at 350 volts, 9 amperes. Light from the arc was received by two spectrographs, one a large Bausch and Lomb Littrow spectrograph with quartz optics, the other a two-meter Allied Research Laboratories grating spectrograph with a 36000-lines-per-inch grating.

Results

The results of analysis for the major constituents of bone meal are presented in table 2. The average levels of the major constituents were very similar to those reported for bone meal by Morrison (1948). Individual samples of bone meal from various sources differed quite widely, even in gross composition. The ranges in protein from 0.13 to 25.4 percent, in fat from 0.02 to 9.29 percent, and in sulfur from 0.07 to 7.27 percent were particularly noteworthy. The amounts of calcium and phosphorus were even quite variable and point toward the importance of buying bone meal on a composition guarantee.

Morrison (1948) lists raw bone meal as containing 0.17 percent sulfur and 0.24 percent magnesium. Steamed bone meal samples analyzed in this study contained 1.43 percent sulfur and 0.57 percent magnesium. The marked difference in sulfur content between the figure listed by Morrison (1948) and that found in this study was due principally to four samples which may not have represented pure bone meal as indicated by this and other aspects of their composition.

The average levels of the minor constituents in bone meal, including the trace minerals, are presented in table 3. All elements listed in this table were determined spectrographically. Copper, zinc, iron, fluorine and manganese were determined quantitatively as described previously. Other minerals reported were determined semi-quantitatively.

Little information is available on the trace mineral content of bone meal. Thus it is difficult to determine if amounts of trace minerals found in this study are typical of amounts usually found in bone meal. As pointed out before, spectrographic sensitivity for the various elements differed. With the procedures employed, no cobalt could be detected. Since the procedures measured down to 10 ppm, it is apparent that levels of cobalt in the material analyzed were less than 10 ppm.

Morrison (1948) reports the iron content of raw bone meal as 0.08 percent. No figures are reported for the manganese or copper content of bone meal, but the content of these materials in an animal product such as tankage is 10.0 mg. manganese per pound and 19.8 mg. copper per pound. Expressed in the same way, the average iron content of the

TABLE 2. PERCENTAGE OF SOME OF THE

TABLE 2. PERCENTAGE OF SOME OF THE MAJOR CONSTITUENTS IN BONE MEAL

Sample No.	Dry Matter	Protein	Ether Extract	Ash	Calcium	Phosphorus	Magnesium	Sulfur
	%	%	%	%	%	%	%	%
1	96.87	5.88	.09	84.29	31.14	14.69	1.15	.18
2	95.33	8.09	.22	80.37	28.98	13.35	.71	.11
3	92.54	5.43	.02	82.64	29.87	14.32	.76	.17
4	92.01	5.07	.04	82.48	29.31	14.35	.60	.16
5	97.23	5.27	.15	85.05	31.42	14.78	.73	.20
6	94.44	3.24	.02	87.45	31.11	14.89	.69	.34
7	91.88	25.40	.66	61.22	22.74	10.67	.55	.12
8	93.22	.28	.25	84.06	22.29	13.74	.29	7.05
9	98.18	.13	.34	88.70	24.97	15.36	.24	7.27
10	97.18	.13	.35	89.01	25.67	16.13	.15	6.17
11	97.44	3.11	.15	88.26	32.01	16.35	.12	.20
12	97.24	6.86	.52	84.07	30.34	15.39	.11	.17
13	97.54	9.59	9.29	72.61	31.00	13.44	.85	.12
14	97.15	6.48	.44	83.30	35.53	15.54	.76	.20
15	98.68	.40	.30	86.36	27.98	11.16	.42	7.00
16	97.02	7.92	.29	80.97	33.53	11.48	.54	.20
17	96.87	12.35	.73	77.39	33.35	12.46	.37	.08
18	96.90	8.61	1.44	77.35	31.51	11.41	.51	.47
19	96.72	6.45	.24	82.42	34.49	12.31	.65	.88
20	98.24	3.40	.20	85.48	35.99	13.83	1.04	.07
21	96.56	6.39	.42	83.42	32.90	13.63	.64	.12
22	97.18	7.15	1.77	80.81	35.34	14.33	.71	.22
Mean All samples	96.20	6.26	0.82	82.17	30.62	13.80	0.57	1.43
Mean Excluding samples 8, 9, 10 and 15	96.06	7.59	0.93	81.09	31.70	13.73	0.64	0.22

TABLE 3. LEVELS OF REHYDRATED ASH AND SOME OF THE MINOR CONSTITUENTS IN BONE MEAL [1, 2]

Sample No.	Rehydrated Ash %	Aluminum ppm.	Barium ppm.	Copper ppm.	Fluorine ppm.	Iron ppm.	Manganese ppm.	Sodium ppm.	Strontium ppm.	Zinc ppm.
1	89.4	400	400	22	1060	250	27	5000	3000	695
2	87.2	9000	350	22	2470	1800	56	5000	2000	570
3	90.1	300	450	5	1180	150	23	5000	5000	540
4	91.4	300	400	21	800	180	27	5000	3000	535
5	90.1	1200	300	21	1050	720	44	5000	700	525
6	94.4	4000	300	24	370	1300	30	5000	900	525
7	67.6	7000	400	20	620	870	117	5000	5000	435
8	85.1	9000	200	83	8760	2900	80	2000	700	700
9	90.2	8000	200	50	8040	3200	51	2000	800	650
10	91.3	8000	90	62	7040	2600	52	2000	900	760
11	92.8	6000	250	19	600	2200	64	5000	400	230
12	89.0	5000	400	20	850	2300	88	5000	1200	245
13	78.0	50	450	5	570	720	24	5000	2000	900
14	89.4	1500	450	7	570	1350	64	5000	5000	220
15	90.8	4000	250	46	7880	2500	51	2000	3000	405
16	86.5	3000	450	4	610	760	81	5000	5000	380
17	83.4	40	350	3	383	180	21	5000	5000	172
18	83.9	1200	200	35	910	2800	81	5000	500	260
19	87.6	1200	200	31	500	780	54	5000	2000	1920
20	88.7	400	300	22	490	300	36	5000	1000	250
21	89.7	1200	450	4	510	330	27	5000	1500	194
22	86.5	400	400	4	910	360	22	5000	600	197
Mean All samples	87.4	3236	329	24	2099	1298	51	4455	2236	514
Mean Excluding samples 8, 9, 10 and 15	87.0	2344	361	16	803	964	49	5000	2433	489

[1] All constituents listed in this table were determined spectrographically.
[2] Levels of mineral elements expressed as ppm. of rehydrated ash.

bone meal samples reported herein was 0.011 percent, manganese 20.3 mg. per pound and copper 9.5 mg. per pound. The sodium content of raw bone meal as reported by Morrison (1948) is 0.74 percent. The sodium content of the samples analyzed in this study, expressed in the same way, was 0.39 percent. No comparative analyses are available for aluminum, barium, strontium or zinc.

In addition to the minerals reported in table 3, many other minerals were detected in some of the bone meal samples. The approximate lower limits of spectrographic sensitivity for other minerals, the number of

TABLE 4. SPECTROGRAPHIC SENSITIVITY FOR AND PRESENCE OF SOME ELEMENTS IN BONE MEAL NOT PRESENT IN ALL SAMPLES

Element	Approximate Spectrographic Sensitivity (ppm)	Number of Samples Containing Detectable Amounts	Largest Amount Found in Any Sample (ppm)
Arsenic	2000	0	...
Boron	100	6	400
Chromium	20	5	500
Cobalt	10	0	...
Lead	500	0	...
Lithium	500	0	...
Molybdenum	100	16	200
Nickel	100	0	...
Potassium	4000	0	...
Silicon	20	22	>10000
Silver	4	1	4
Tin	100	0	...
Titanium	20	11	600
Vanadium	100	4	450

samples (out of a total of 22 analyzed) containing detectable amounts of the mineral in question, and the largest amount in any one sample are shown in table 4.

In surveying the results as a whole, it appears that samples 8, 9, 10 and 15 differed in many respects from the other samples analyzed. Nutritionally, one of the more important differences was in the amount of fluorine. The four samples mentioned above were approximately 10 times as high in fluorine content as were the other samples. Many of the samples analyzed in this study fell within the normal range reported by Chang *et al.*, (1934) for bone of 42 to 63 mg. per 100 gm. of dried bone. However, the four samples mentioned above fell considerably outside this normal range. A possible explanation for this discrepancy is

that the bone meal samples in question had become contaminated with raw rock phosphate.

In addition to the difference in fluorine, samples 8, 9, 10 and 15 contained less protein, more sulfur and slightly less calcium than did the other samples analyzed. Moreover they were highest in content of aluminum, copper and iron. In addition they were high in silicon, boron, chromium and titanium. They were the only samples analyzed in which vanadium was present in large enough amounts to be detectable by the methods used.

Since samples 8, 9, 10 and 15 varied considerably from the other samples analyzed it would seem that the most valid values for pure bone meal could be obtained by omitting these four samples from the mean. When this is done, greatest influence is noted on the average amounts of protein, sulfur, aluminum and fluorine. As indicated in tables 2 and 3, when samples 8, 9, 10 and 15 are omitted from the mean, protein is increased from 6.26 percent to 7.59 percent, sulfur decreased from 1.43 percent to 0.22 percent, aluminum decreased from 3236 ppm. to 2344 ppm. and fluorine decreased from 2099 ppm. to 803 ppm.

Discussion

In discussing the suitability of any material as a mineral supplement, it is important to know how much of the nutritionally necessary elements are contained. A material such as bone meal is well suited for use as a calcium and phosphorus supplement, because even after it is diluted with concentrates at usual rates (1 to 100), it furnishes a sizable amount of calcium and phosphorus for the animal. Thus the average bone meal found in this study, added at a 1 percent level to a grain ration completely devoid of calcium, would still provide 0.30 percent calcium in the grain ration. This is in excess of the amounts recommended by Loosli *et al.* (1950) in the ration of the dairy cow.

The study reported herein has shown that bone meal is a very complex material. Its adequacy as a trace mineral supplement, however, must be studied in relation to the trace mineral needs of livestock. If, for example, one wished to provide a copper supplement for a grain ration in a copper deficient area, bone meal would not be a very effective supplement. Adding bone meal at a 1 percent level to a grain ration completely deficient in copper would result in a grain mix containing only 0.24 ppm. of copper. Since the copper needs of animals are said to be 5 to 7.5 ppm. in the diet, it is apparent that a bone meal supplement would not raise the copper content of the ration satisfactorily.

Likewise, since the bone meal samples analyzed in this study contained less than 10 ppm. of cobalt, it could not be considered a good source of this element. Bone meal is a relatively better source of iron, manganese, and zinc. However, the requirements for the latter two have not been determined for most domestic animals.

Summary

Twenty-two bone meal samples, 14 of which were of foreign origin, were analyzed for their major and minor constituents. Four of the samples appeared to be contaminated and not to represent pure bone meal. When these were omitted, average levels of the major constituents determined were protein, 7.59 percent; ether extract, 0.93 percent; ash, 81.09 percent; calcium, 31.70 percent; phosphorus, 13.73 percent; magnesium, 0.64 percent; and sulfur, 0.22 percent. Average levels of minerals determined spectrographically (omitting samples contaminated with phosphate rock) were as follows (expressed as ppm. of rehydrated ash): aluminum, 2344 ppm.; barium, 361 ppm.; copper, 16 ppm.; fluorine, 803 ppm.; iron, 964 ppm.; manganese, 49 ppm.; sodium, 5000 ppm.; strontium, 2433 ppm.; and zinc, 489 ppm. In addition, boron chromium, molybdenum, silicon, silver, titanium, and vanadium were found in one or more of the samples.

The study reported herein has shown the complexity of bone meal. However, contents of such trace minerals as copper and cobalt are too low for bone meal to be of much value as a supplement for these two elements. It is a much better source of iron, manganese and zinc in addition to its established role as a calcium and phosphorus supplement.

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EFFICIENCY AND EFFECTIVENESS OF SELECTION IN CROSSBRED SWINE

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SELECTION studies have received considerable attention in the Regional Swine Breeding Laboratory during recent years. These studies have been concerned primarily with selection in inbred lines. The results of a cooperative study of selection in inbred lines are reported by Dickerson *et al.* (1953). In general, these results have indicated that progress is not as rapid as might be expected on the basis of selection differentials and heritability estimates for productivity items. The purpose of this investigation was to study selection for productivity traits in a swine herd of crossbred origin.

Material and Methods

Nebraska initiated a crossbreeding project at the Lincoln Station in the spring of 1946. Initial crosses were Landrace x Duroc. Two Landrace boars obtained from the Beltsville Station were mated to ten gilts from North Platte Line 10, to farrow in the spring of 1946, and to 10 gilts from the Lincoln outbred herd to farrow in the fall of 1946. Six gilts from the spring of 1946 farrow and 17 from the fall farrow were mated to farrow in the fall of 1947. Two Duroc, two Landrace, three Berkshire, and two F_1 (Landrace x Duroc) boars sired the 1947 litters. Thirty-seven litters were sired by three Berkshire and two Yorkshire boars in 1948. After 1948, the herd was closed until 1951 when a crossbred boar was brought from Beltsville. Four boars were used in 1949, eight in 1950, and four plus the imported crossbred boar in 1951. All females used in the project farrowed as gilts, no second litters being produced. All pigs were sired by young boars, except those sired by the two original Landrace boars in the fall of 1946, and one Berkshire in 1948. With the exception of the first season, all litters were produced in the fall. Pigs produced were fed in litter groups following weaning. All groups were fed corn, supplement and mineral free choice.

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Characters studied and symbols used were: number of pigs farrowed (N_O), number of pigs weaned (N_{56}), total weight of litter at weaning (T_{56}), average weaning weight per pig ($\overline{X}_{56}$), weight of the individual pig at weaning (W_{56}), individual pig weight at 154 days (W_{154}), inbreeding of the dam (F_D), inbreeding of the individual pig (F_I), and an index of the pig at 154 days (I). The first four characters are influenced by the dam and were considered as sow productivity items. In the analysis the other five characters were treated as individual performance items. Since all litters were produced by gilts, age of dam was not considered. Inbreeding was measured by Wright's (1922) coefficient of inbreeding. Average weaning weight per pig ($\overline{X}_{56}$) was obtained by dividing total weight of the litter at weaning by the number weaned. The index used in this study was one proposed by Dickerson (1948) where $I = 2\ (N_O + 2\ N_{56} + \frac{T_{56}}{15}) + W_{154}$.

Weights were obtained at 56 and 154 days in all seasons except the fall of 1950, when it became necessary to weigh some litters at slightly different times in order to utilize more efficiently the facilities at the station. A formula derived by Whatley and Quaife (1937) was used to adjust 56-day weights, and 154-day weights were adjusted to a standard age by a formula derived by Lush and Kincaid (1943).

Data from 1079 weanling pigs produced in 162 litters were analyzed using formulas and methods of Dickerson *et al.* (1953). The analysis was made on an intraseason basis with each mating type being carried separately.

Results and Discussion

Annual selection differentials for dams (D), sires (S), and the average of the two parents (P) for the items studied are summarized in table 1. Average selection differentials for inbreeding are essentially zero. It should be pointed out here that selection differentials for sires (S) were not calculated for the first four seasons as the sires used were brought in from herds on which data were unobtainable.

Average annual selection differentials for sires and dams are presented in terms of standard deviations in table 2. That the averages for sires and dams are essentially the same except for (W_{56}) and (W_{154}) may be a reflection of the fact that the values for sires are for a small number of seasons. A more likely explanation is that greater emphasis was placed upon (W_{154}) when boars were selected and correspondingly high values for (W_{56}) and for (I) followed automatically.

TABLE 1. AVERAGE ANNUAL SELECTION DIFFERENTIALS

Season	△[2]	Characters Studied [1]								
		N_o	N_{56}	T_{56}	$\overline{X}_{56}$	W_{56}	W_{154}	F_D	F_I	I
S46	D	1.16	1.13	24.32	—1.52	—.54	—6.87	0.00	.99	1.34
F46	D	.02	.78	15.58	—1.20	4.35	....	0.00	.85	....
F47	D	.13	.15	7.98	.24	1.40	1.58	—.35	0.00	—.09
F48	D	.10	.27	6.16	.50	1.30	5.79	0.00	—.06	6.06
F49	D	—.04	.13	6.58	.56	5.85	17.27	.03	0.00	18.77
	S	—.07	.46	18.30	.74	5.54	33.91	0.00	0.00	39.34
F50	D	.04	.34	13.34	.59	4.16	14.54	0.00	—1.32	12.88
	S	.24	.57	19.59	.07	6.56	31.49	0.00	—1.97	36.49
F51	D	.23	.46	9.30	—.50	2.28	3.61	—1.02	—.03	6.57
	S	—.21	.14	8.58	.28	5.59	31.90	.86	—1.34	34.14
Av.	D	.23	.46	11.89	—.19	2.68	5.99	—.19	.06	7.59
	S	—.01	.39	15.49	.36	5.90	32.43	.29	—1.10	36.66
	P	.11	.42	13.69	.08	4.29	19.21	.05	—.52	22.12

[1] The symbols used are:
N_o—Number of pigs farrowed.
N_{56}—Number of pigs weaned.
T_{56}—Total weight of litter at weaning.
$\overline{X}_{56}$—Average weaning weight per pig in the litter.
W_{56}—Weight of the individual pig at weaning.
W_{154}—Individual pig weight at 154 days.
F_D—Inbreeding of dam (in percent).
F_I—Inbreeding of litter (in percent)
I—Index of the pig at 154 days.

[2] △D—Average for dams.
△S—Average for sires.
△P—Average for parents.

TABLE 2. AVERAGE ANNUAL SELECTION DIFFERENTIALS IN STANDARD MEASURE

Parent	Percent Saved	Characters Studied [1]								
		N_o	N_{56}	T_{56}	$\overline{X}_{56}$	W_{56}	W_{154}	F_D	F_I	I
$\overline{D}$	35	.09	.19	.17	—.02	.34	.18	—.03	.01	.22
$\overline{S}$	4.5	.00	.16	.22	.05	.75	1.00	.04	—.13	1.05

[1] See footnote table 1 for description of symbols.

On the basis of percentages saved the maximum selection differentials attainable in terms of standard deviations would be approximately 1.06s for dams and 2.11s for sires (Lush 1945, table 12) if selection were for a single trait and strictly by truncation. A comparison with index values (table 2) for all seasons indicates that selection expressed as a percentage was only 20.6 and 49.8 percent of the maximum attainable for dams and sires, respectively, even though use was made of a selection index.

The results of automatic, deliberate, and net (total) selection for sow productivity items are presented in table 3. Automatic selection arises because more animals are available from larger litters and have an opportunity to be selected. Deliberate selection is that which was practiced—over and above that which is automatic. Net or total is the sum of the two. In most cases automatic selection accounts for a larger part of the total than does deliberate. Since the values in table 1 have been divided by 2, to account for the fact that individuals receive only half of their inheritance from their dams, a direct comparison with values of table 3 cannot be made. Slight discrepancies may appear in the averages of all seasons because values were not available for sires in all seasons. All values obtained, however, appear to be additive within the tolerance of rounding error.

In most cases deliberate selection for N_O was negative, indicating that attention was paid to other characteristics. This suggests, but does not prove negative correlations between N_O and some characteristics to which considerable selection pressure was applied.

Definite conclusions as to the effectiveness of selection for all organisms studied may not be made on the basis of literature reviewed with this study. Dissimilarity between species of animals in their response to selection is indicated. Other workers report progress by means of selection with experimental animals in which single characteristics of a quantitative nature have been studied. Results of reports of selection studies with farm animals for similar characteristics, such as egg production of chickens, and milk and butterfat production of dairy cattle are similar. In all cases, however, production has declined in swine in spite of positive selection differentials for productivity items. In swine, selection has been on the basis of net merit which is a measure of several items or characteristics, each of which is quantitative in nature.

TABLE 3. AUTOMATIC, DELIBERATE AND NET SELECTION PER YEAR FOR PERFORMANCE OF DAMS

Season	Selection	Sex	N_o	N_{56}	T_{56}	X_{56}
S46	Auto.		.77	.85	21.14	—.99
	Del.	Gilts	1.56	1.41	27.49	—2.04
	Net	Gilts	2.33	2.26	48.63	—3.03
F46	Auto.		.45	.76	16.52	—1.13
	Del.	Gilts	—.41	.81	14.64	—1.28
	Net	Gilts	.04	1.57	31.16	—2.41
F47	Auto.		.33	.44	11.54	—.37
	Del.	Gilts	—.07	—.14	4.41	.86
	Net	Gilts	.26	.30	15.95	.49
F48	Auto.		.44	.75	15.42	—.65
	Del.	Gilts	—.25	—.22	—3.10	1.64
	Net	Gilts	.19	.53	12.32	.99
F49	Auto.		.32	.49	10.37	—.29
	Del.	Boars	—.47	.42	26.24	1.77
		Gilts	—.40	—.23	2.78	1.41
		Average	—.44	.09	14.51	1.59
	Net	Boars	—.15	.91	36.61	1.48
		Gilts	—.08	.26	13.15	1.12
		Average	—.12	.58	24.88	1.30
F50	Auto.		.72	.91	21.36	—.44
	Del.	Boars	—.25	.22	17.82	.58
		Gilts	—.63	—.23	5.32	1.62
		Average	—.44	—.01	11.57	1.10
	Net	Boars	.47	1.13	39.18	.14
		Gilts	.09	.68	26.68	1.18
		Average	.28	.90	32.93	.66
F51	Auto.		.54	.75	17.38	—.89
	Del.	Boars	—.96	—.47	—.23	1.45
		Gilts	—.08	.16	1.22	—.10
		Average	—.52	—.15	.50	.68
	Net	Boars	—.42	.28	17.15	.56
		Gilts	.46	.91	18.60	—.99
		Average	.02	.60	17.88	—.22
All	Auto.		.51	.71	16.25	—.68
	Del.	Boars	—.56	.06	14.61	1.27
		Gilts	—.04	.22	7.54	.30
		Average	—.30	.14	11.08	.78
	Net	Boars	—.03	.77	30.98	.73
		Gilts	.47	.93	23.78	—.38
		Average	.22	.85	27.38	.18

[1] See footnote table 1 for description of symbols.

The effects of inbreeding in animals have been investigated by numerous workers. Dickerson *et al.* (1947) reported for each 10 percent increase in inbreeding of litter, independent of age and inbreeding of dam, a decline of .2 pig at birth, .5 pig at 56 days and no decline in pig weight at 56 days, but a 3.6 pounds decline in pig weight at 154 days. They also reported a decline for each 10 percent increase in inbreeding of dam of .16 pig at birth and .22 to .25 pig at 21 to 154 days of age.

The decline in sow productivity as evidenced by the data used in this study is not as great as might be expected. Selection partially but not entirely overcame the decline which would normally be expected with mild inbreeding. Kottman (1952) found a decline in productivity greater than that attributable to inbreeding. Real differences between the results and the calculated values do not seem likely since sampling errors are large in a small population. On the other hand, W_{154} increased 32.96 pounds where a decline of 6.99 pounds might have been expected from the results of Dickerson *et al.* (1947). This gain cannot be attributed to selection, however, since W_{154} was relatively constant in seasons prior to 1950. The difference is believed to be due largely to antibiotics which were fed for the first time in the fall of 1950.

If the better individuals, which were selected as parents, were actually better because of their genetic constitution, then the level of merit in the next generation should be raised. Numerous investigators have reported estimates of heritability for sow productivity items. The estimates of 15 percent for number farrowed, (Craft, 1953); 17 percent for number weaned and 18 percent for litter weight at weaning (Lush and Molln, 1942), were applied to the annual selection differentials calculated for the respective items in this study. Application of these estimates gave expected values of .07 pig, .28 pig and 9.84 pounds in contrast to actual values of —.10 pig, —.19, and —22.11 pounds for N_0, N_{56}, and T_{56} respectively. These results are in agreement with other reports of selection in swine where productivity has declined despite positive selection differentials for productivity items.

The failure of selection to produce expected results in swine calls for some explanation. One answer may be found in environmental variance and its interaction with heridity. Since environment did vary somewhat from one season to another, the interaction of genotypes with environment may have been an important factor. Heritability

estimated on the basis of performance within a single season would be much too high if genotype-environment interactions are of an appreciable magnitude. This seems to be a rather weak explanation since environmental conditions were controlled insofar as possible in this project and since similar results are reported for swine by other stations. Some other source of variance or some other mechanism must be of importance in accounting for the failure of selection to produce expected results with swine.

Lush (1945) refers to two conditions which modify the rate at which selection tends to change a population. The first condition, in which the heterozygote is better than either homozygote, is called overdominance. A second is epistasis, in which selection for a gene in one combination is balanced by selection against that gene when in another combination. Kottman (1952) mentions a third consideration, negative genetic correlations, which may play as important a role as either overdominance or epistasis insofar as selection for net merit is concerned. If most of the phenotypic variability of a population upon which selection is practiced is due to one or more of these causes, a breeder may select intensively for a long period of time, even with a selection index, without making improvement in the population.

A breeder, if selecting at the same time for two traits between which negative correlation exists, may be marking time. Lush (1948) suggested reasons for suspecting negative correlations in populations which had been under selection for a long time. This problem is discussed by Lerner (1950) who credits L. N. Hazel with the explanation of how a negative relationship might arise automatically between two desirable traits, although they were not so correlated at the beginning of a selection program.

Slightly negative correlations between productivity and 180-day weights were reported by Hazel (1943). Since large sampling errors were likely, he concluded that the small negative values which he obtained were not significantly different from zero. The positive correlation (.87) between body weight and shank length, reported by Lerner *et al.* (1947) may be considered as negative since the fryer trade desires short shanks and heavy body weight (Jaap, 1941). Lerner and Dempster (1951) reported that a lower reproductive rate was associated with longer shank length. Also of interest is the report of Shultz and Briles (1953) who found that selection for high egg production in a production-bred line of chickens favored the heterozygotes at the A (blood group) locus.

Mather (1941, 1942) has proposed another explanation for unfavorable correlated responses. In his hypothesis there occur polygenic combinations in which linkage of plus and minus genes is balanced. According to Mather, selection imposed upon a population already in (or near) equilibrium upsets the balance of polygenes so that unfavorable combinations for apparently unrelated traits limit progress until a time when new favorable combinations are formed by selection of crossover types. Mather and Harrison (1949) present results of selection experiments with Drosophila which they hold as verifying Mather's hypothesis.

Direct application of results of Drosophila experiments to farm animals does not seem proper at this time for two reasons. First, no crossing-over occurs in the male of Drosophila, and secondly, farm animals have a much larger chromosome number. The second consideration might seem to be excellent material for application of Mather's hypothesis since there are more chromosomes and hence a greater possibility for more blocks of genes. However, selection for any one such block or unit is unlikely to be intense enough to distort the random order of gene combinations seriously. Mather's hypothesis seems to be of little consequence in animals where large numbers of genes influence a character, unless some mechanism leads to distortion of the random order of gene combinations. This question of course is open for much discussion and the answer is not readily available at this time. Lerner (1951) has reported the occurrence of a delayed response which followed an early marked response to selection. His report seems to lend support to Mather's hypothesis, but more work is in order before definite conclusions may be drawn concerning balanced polygenic combinations of hereditary units and their significance in the selection of farm animals.

At the present time evidence that negative genetic correlations are the important cause for the failure of selection to improve performance in swine is inconclusive. Neither have the roles of epistasis and overdominance been clarified so that their effects on progress by selection can be used to explain the failure of selection to make genetic improvement in the lines studied. Until such time as techniques are devised for study and evaluation of epistatic and dominance relationships, they may be offered only as possible explanations.

Summary and Conclusions

The efficiency and effectiveness of selection practiced on a mildly inbred herd which started as a crossbred herd were estimated. Data

from 1079 pigs weaned in 162 litters during the period from the spring of 1946 through the fall of 1951 were used in the study.

Selection differentials for inbreeding of dam and of litter were essentially zero, indicating that the expected depressing effects of inbreeding were not severe enough to influence selection of other characteristics studied.

If selection were for a single trait and strictly by truncation, the maximum size of selection differentials, attainable on the basis of percentages saved, in terms of standard deviations would be 1.06s for dams and 2.11s for sires. Efficiency of selection for an index, in terms of the maximum attainable, was 20.6 percent for dams and 49.8 percent for sires.

Automatic selection, in most cases, accounted for a greater portion of total selection than deliberate selection.

Means and standard deviations remained relatively constant for all productivity items throughout all seasons. Extremes were segregating as evidenced by mean number farrowed in some mating types in later seasons. This is as would be expected, however, and did not alter the overall means and standard deviations for the season. The results of the study make possible the following statements:

Production declined despite positive selection differentials for productivity items and net merit. The level of production was not raised in this herd.

Production did not decline in this herd to the extent that is normally expected with inbreeding. On this basis selection can be said to be effective in partially overcoming such depressing effects.

The results of this study are considered to be in agreement with other swine selection studies in which selection for productivity and net merit has failed to raise the level of production. This seems to indicate a peculiar relationship between physiological processes in the pig and characteristics which were considered as productivity items.

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THE EFFECT OF TESTOSTERONE AND CASTRATION ON THE GROWTH AND CARCASS CHARACTERISTICS OF SWINE[1]

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THE effects of castration and androgen administration on meat producing animals have not been studied extensively. Hunt (1938) found that rams carried a higher percentage of lean in the rib cuts than did wethers. Andrews, Beeson and Harper (1949) reported that testosterone increased feed efficiency and carcass quality of wether lambs, while Andrews, Beeson and Johnson (1950) reported no effects with steers. Burris *et al.* (1952) found that rate of gain and feed efficiency was increased by testosterone treatment of steer and heifer calves. O'Mary *et al.* (1952) found no effects due to testosterone with sheep and Woehling *et al.* (1951) reported similar results with swine. Winters *et al.* (1942) concluded that growth differences between boars and barrows were due largely to differences in the skeleton and deposition of fat as determined by live animal measurements. Hammond and Murray (1937) found that castrated males and females had thicker backfat measurements than the corresponding entire animals, while the entire females had more fat than the entire males. Baker (1927) found that the seminal vesicles, Cowper's glands and adrenals are smaller when castration was performed at 100 days than when done at 200 days, and there is little difference if castration is performed at 50 or 100 days. Nordby and Gildow (1933) found that the testes of normal boars were twice as large as the testes of cryptorchids.

German investigators have been concerned with the sexual odor of meat from boars and cryptorchid boars. Lerche (1936) concluded that sex odor could be detected in the cooked parotid gland even though the meat and fat gave negative results. The odor was found in carcasses from boars slaughtered 75 days after castration.

The present study was made to determine the effect that delayed castration and testosterone administration would have on the carcass characteristics, particularly muscular development, of fattening swine.

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Experimental Procedure

Twenty-four boar pigs of a Poland China-Hampshire-Duroc cross were divided into six lots when 70 days of age at an average weight of 40.4 lb. Lots 1 and 2 were castrated at the beginning of experiment. Lot 1 was the normal barrow controls. Pigs in Lot 2 were implanted with 193 milligram pellets of testosterone propionate in the muscular tissue at the base of the ham at the time of castration. Lots 3, 4, and 5 were castrated at weights of 100, 140 and 180 pounds respectively. Lot 6 was left as normal boar controls.

All lots were self fed on rape pasture a ration of ground corn, ground oats, soybean oil meal, meat scraps and mineral mixture. Individual weights and lot feed consumption were recorded every two weeks. All animals were taken off feed at weights between 210 and 230 pounds, and slaughtered 24 hours later. Immediately after bleeding and dehairing the sex accessory glands were removed. The seminal vesicles (vesiculae seminales) were tied off at the excretory ducts to lessen the loss of fluid. The body of the prostate was weighed with the seminal vesicles plus the vesicular fluid, as the prostate body, being concealed by the seminal vesicles, was difficult to dissect without loss of fluid. The Cowper's glands (bulbo-urethral) and fluid contents were weighed after removing the layer of striated muscle (M. bulbo-glandularis). The prepuce was removed and examined and the testicle weights of the boar controls were recorded.

All hogs were dressed packer style with cold carcass weights taken after 24 hours storage at 32–36° F. Length of body, leg length, backfat thickness and weights of the preferred cuts—skinned ham, New York skinned shoulder, barrow style belly, pork loin—were taken. A tracing of the rough loin (pork loin plus backfat) was made of the anterior surface of the last rib. Eight chops from each carcass were used for duplicate cooking and palatability tests.

Results and Discussion

Comparisons of feed consumed per pound of gain, days on experiment, initial and final weight and average daily rate of gain by lots are shown in table 1. Statistical treatment of the differences in daily rate of gain between the lots did not show any significance. This is in agreement with Hunt (1938) who found no significant difference in the average rates of gain made between rams and wethers. The mean

TABLE 1. THE EFFECT OF TESTOSTERONE AND CASTRATION ON GROWTH, FEED CONSUMPTION AND FEED EFFICIENCY

Item	Lot 1 Barrow Controls	Lot 2 Testosterone Implanted Barrows	Lot 3 Castrated 100 lbs.	Lot 4 Castrated 140 lbs.	Lot 5 Castrated 180 lbs.	Lot 6 Boar Controls
Number of pigs	4	4	4	4	4	4
Initial wt. lb.	41.5	40.3	41.5	40.5	39.3	39.8
Final wt. lb.	219.8	220.3	216.3	217.3	227.3	224.3
Days on experiment	126	118	120	112	133	139
Daily gain per pig	1.41	1.52	1.46	1.57	1.42	1.31
Feed per lb. gain	3.81	3.80	3.96	3.58	3.67	3.84

feed consumption per pound of gain was 3.79 pounds. None of the lots varied appreciably from this mean.

A summary of the carcass data is presented in table 2. The higher dressing percent of the barrows of Lots 1 and 2 and the 100 pound castrates would be expected as these lots also showed a higher degree of finish as determined by backfat thickness. The 140 and 180 pound castrates, and boar controls were longer in body than the other lots.

In percent of preferred cuts on a liveweight and carcass basis, Lots 5 and 6 were significantly higher. This would be expected when fatness, as measured by average backfat, is taken into consideration. In comparing the performance of swine in breeding and feeding projects

TABLE 2. THE EFFECT OF TESTOSTERONE AND CASTRATION ON CARCASS CHARACTERISTICS AND PALATABILITY OF CHOPS

Item	Lot 1 Barrow Controls	Lot 2 Testosterone Implanted Barrows	Lot 3 Castrated 100 lbs.	Lot 4 Castrated 140 lbs.	Lot 5 Castrated 180 lbs.	Lot 6 Boar Controls	L.S.D.[4]
Number of pigs	4	4	4	4	4	4	
Approximate age castration, days	70	70	126	143	169	Boar Controls	
Dressing %	74.0	73.7	74.0	71.6	72.9	72.2	0.98
Carcass body length (in.) [1]	28.6	28.9	28.6	29.5	29.6	30.8	0.47
Av. backfat (in.) [2]	1.75	1.68	1.74	1.43	1.43	1.06	0.22
Preferred cuts:							
Carcass basis	64.9	64.6	65.8	68.0	68.8	72.8	1.76
Liveweight basis	48.0	47.6	48.6	48.7	50.2	52.6	1.30
Percent lean in rough loin cross-section	40.9	39.8	41.6	45.7	51.2	61.7	8.83
Palatability scores [3]	4.7	4.5	4.5	4.8	4.7	3.3	0.54

[1] Between anterior edges of aitch bone and 1st rib.
[2] Average of 1st rib, last rib and last lumbar measurements.
[3] Scores—1 very poor to 7 excellent.
[4] Least significant difference at 1% level.

when carcass characteristics are an important measure, boars or delayed castrates should not be compared directly with normal barrows and gilts. Without exception, the boar controls had a higher liveweight and carcass preferred cut yield than any pig in this experiment. The percent lean in the rough loin cross section was correlated with carcass cut-out and also liveweight cut-out. The values for r were .86 and .82 respectively (P=0.01).

The pork produced by Lot 6 was soft, dark colored and lacked marbling. In addition, it was definitely inferior from a palatability standpoint. Cooking of the chops by braising produced a definite "off" or "boar" odor during the cooking which carried through to the

TABLE 3. THE EFFECT OF TESTOSTERONE AND CASTRATION ON ACCESSORY SEX GLANDS AND KIDNEY WEIGHTS

Item	Lot 1 Barrow Controls	Lot 2 Testosterone Implanted Barrows	Lot 3 Castrated 100 lbs.	Lot 4 Castrated 140 lbs.	Lot 5 Castrated 180 lbs.	Lot 6 Boar Controls	L.S.D.[2]
Number of pigs	4	4	4	4	4	4	
Days between castration and slaughter	126	118	66	40	34	0	
Seminal vesicles plus prostrate (gm.)	1.2	1.7	5.8	14.3	28.3	420.0	
Cowper's glands (gm.)	2.6	3.1	9.2	17.4	55.9	179.0	
Kidneys (gm.)	257.0	268.0	274.0	282.0	309.0	339.0	28.8
Testes (gm.)						438.0	
Palatability scores[1]	4.7	4.5	4.5	4.8	4.7	3.3	0.54

[1] Scores—1 very poor to 7 excellent.
[2] Least significant difference at 1% level.

cooked product. No objectionable odor was detected in the chops from the 180 lb. castrates. It was concluded that castrating 6-months-old 180 lb. boars five weeks (21–44 day range) prior to slaughter eliminated the undesirable odors associated with boar meat.

Weights of accessory sex glands and kidneys are given in table 3. Kidney weights of the boar controls and the 180 pound castrates were significantly greater than in any of the other lots. While the accessory sex gland weights of the delayed castrates were larger than those of the normal barrows, atrophy was extremely rapid after castration. The gland weights of the 180 lb. castrates were only a fraction of those of the boar controls. Leathem (1948) found that testosterone propionate increased the kidney weight of rats in which food intake was restricted, and was equally effective in thiourea-fed and normal rats.

Examination of the prepuce gave varying results. Barrows of Lot 1 showed atrophy of the preputial sac with very little necrotic tissue

present. Two barrows of Lot 2 gave indications that involution was complete. The 100 and 140 pound castrates had some bloody fluid in the preputial sac which indicated that involution was almost complete. Two of the 180 pound castrates slaughtered 3 and 4 weeks after castration, showed much bloody fluid and free epithelial tissue indicating an active process of involution. The preputial sac of the boar controls showed healthy epithelial tissue lining the sac and the lumen contained a milky fluid.

The preputial sac of the 180 pound castrates and the boar controls produced a strong "pig pen odor" while the other lots had a strong "urine odor". McKenzie, Miller and Bauguess (1938) stated that fresh semen has no odor except when contaminated with urine or contents of the preputial pouch. They further mentioned that the preputial pouch contained decomposing urine and cellular debris which have a disagreeable odor and constitute the characteristic sexual odor of the boar.

Lot 2 barrows were implanted with one 193 mg. pellet of testosterone propionate each at the base of the ham at the time of castration. Pellets from two barrows were recovered which showed a total absorption of 60.1 and 57.4 milligrams. The results of this study did not reveal any significant differences between the implanted barrows and the control barrows. Apparently absorption was not great enough. Sleeth *et al.* (1953) found that the injection of testosterone proprionate in barrows at the rate of 1 mg. or of 0.5 mg. per kg. of body weight weekly or semi-weekly did not produce significant carcass differences. It would appear that a very large amount of testosterone is necessary to affect or change the growth and fattening characteristics of swine.

The results of this study show that the carcass characteristics of swine can be altered by delayed castration. The practicability of this method is questionable as all of the boars in this experiment showed evidence of sexual maturity at four to five months of age. Another economic consideration would be the possibility of excessive death loss and the difficulties involved in handling large animals during the operation.

Summary

Carcass comparisons of the boars and barrows of different castration weights showed that the boars and 180 pound castrates had a higher percent of lean in the rough loin, less backfat, longer body length and a higher liveweight and carcass preferred cut yield. Quality of the pork produced by boars was inferior in all respects. Acceptability tests

showed that the boars produced pork that had a definite "off" flavor and odor. The accessory sex glands and kidney weights of the boars were heavier and the weights decreased very rapidly as the weights of castration decreased. There was no significant difference in sex accessory gland and kidney weights between normal barrows and barrows implanted with 193 mg. pellets of testosterone proprionate. No objectionable odor or flavor was found in pork produced by animals castrated an average of 5 weeks prior to slaughter. Rate of gain and amount of gain per pound of feed was not affected by testosterone pellet implantation, delayed castration or by non-castration.

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THE INFLUENCE OF AUREOMYCIN ON THE PROTEIN REQUIREMENT AND CARCASS CHARACERISTICS OF SWINE [1]

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MANY experiments have been conducted over the years in an attempt to establish the optimum protein allowance for growing swine. Suggested allowances have not always been in good agreement. It is very probable that some of the variation in suggested allowances has been a reflection of differences in overall nutrient balance of test rations. As swine rations improve with advances in nutritional knowledge, it is apparent that protein allowances may need to be altered for maximum efficiency and economy. Several recent studies have reported that less protein is required when the ration is fortified with antibiotic, B_{12} and other members of the B-complex vitamin group (Cunha *et al.*, 1950; Burnside *et al.*, 1951; Catron *et al.*, 1952; and Hoefer *et al.*, 1952).

This study was designed with three objectives in mind: First, to determine the optimum level of protein for a practical, corn-soybean oil meal type ration well fortified with B-vitamins and trace minerals; secondly, to determine if the presence of an antibiotic in the ration makes it feasible to alter the amount of protein; and thirdly, to study the influence of different levels of protein with and without antibiotic on the desirability of carcasses produced. In view of the ever present shortage of proteinaceous feedstuffs for swine feeding and the emphasis on the improvement of carcass quality by increasing total lean cuts, additional information on these three points seemed extremely important.

Experimental Procedure

Forty-two purebred Duroc and twelve crossbred Duroc x Hampshire weanling pigs were divided according to breed, litter, weight, and sex into six similar experimental groups. The pigs were approximately

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nine weeks old at the start of the experiment and they averaged slightly over 40 pounds in weight. The animals were maintained in concrete pens which were cleaned and hosed down daily.

The experimental rations shown in table 1 were self fed. Two groups of pigs were started on each of the following levels of crude protein: 14.3, 17.6, and 20.9 percent. Henceforth, these will be referred to as the low, intermediate, and high protein rations, respectively. Aureomycin

TABLE 1. EXPERIMENTAL RATIONS [1]

Ration Compound	Protein Percentage			
	11.7	14.3	17.6	20.9
	(parts)			
Ground Yellow Corn	86	78	69	61
Expeller Soybean Oilmeal	7	15	24	32
Alfalfa Leaf Meal	5	5	5	5
Limestone	1	1	1	1
Steamed Bone Meal	0.5	0.5	0.5	0.5
Salt-trace Minerals [2]	0.53	0.53	0.53	0.53

[1] The following levels of B-complex vitamins were added to all rations per 100 pounds of feed: thiamine, 1.0 gm.; riboflavin, 230 mg.; niacin, 2.33 gm.; pantothenic acid, 1.0 gm.; pyrodoxine, 375 mg.; choline, 19.4 gm.; folic acid, 11.6 mg.; and vitamin B_{12}, 1 mg. The aureomycin and B-vitamins used in this study were generously supplied by Lederle Laboratories, Pearl River, New York.

[2] The salt-trace mineral mixture was composed of: iodized salt, 50 lbs.; manganese sulfate, 921 gm.; ferrous sulfate, 398 gm.; copper sulfate, 125 gm.; and cobalt carbonate, 10 gm.

was added at a level of 20 grams per 100 pounds of feed to the ration of one group of pigs on each of the protein levels. As the average weight of the pigs in the various lots approached 100 pounds, each lot of pigs was changed to the ration containing the next lower amount of protein. The pigs that were started on the low level of protein were changed to a ration that contained 11.7 percent of protein (table 1).

Hemoglobin readings were recorded for all animals at the start of the experiment and every two weeks thereafter.

Results and Discussion

A summary of the experimental results is presented in table 2 and a statistical analysis of the data is found in table 3.

Average Daily Gains

The gains from weaning to 100 pounds on the low intermediate, and high protein levels without antibiotic were 1.09, 1.16, and 1.02,

TABLE 2. THE EFFECT OF AUREOMYCIN AND PROTEIN LEVEL ON GROWTH, FEED EFFICIENCY, AND CARCASS CHARACTERISTICS OF SWINE

Experimental Rations	Low Protein	Low Protein+ Aureomycin	Intermediate Protein	Intermediate Protein+ Aureomycin	High Protein	High Protein+ Aureomycin
Initial no. of pigs	9	9	9[1]	9[1]	9	9
Av. initial wt., lb.	41.6	41.6	44.0	43.9	41.0	40.6
Av. daily gain to 100 lbs., lb.	1.09	1.17	1.16	1.13	1.02	1.09
Av. daily gain, entire period, lb.	1.37	1.54	1.46	1.43	1.37	1.43
Av. final wt., lb.	188.4	194.9	190.9	187.1	187.4	190.1
Av. daily feed per pig, lb.	4.82	5.24	4.45	4.39	5.10	4.77
Feed per pound gain, lb.	3.64	3.58	3.06	3.10	3.72	3.40
Av. hemoglobin	8.8	9.1	9.6	9.7	9.4	9.7
Dressing percentage[2]	80.2	81.8	81.8	80.1	78.3	80.7
Back fat thickness, in.[3]	1.81	1.96	1.83	1.83	1.67	1.87
Body length, in.[4]	27.7	28.3	27.5	27.0	27.8	27.9
Body depth, in.[5]	13.1	12.8	13.2	13.1	12.3	13.3
Distribution of carcasses in the various grades:[6]						
C-1	5	3	2	4	6	2
C-2	2	3	4	3	1	5
C-3	1	3	1	1	0	1
Medium	0	0	1	0	1	1

[1] One pig removed early in experiment because of failure to grow.
[2] Warm carcass, head and leaf fat on.
[3] Average of measurements at first rib, last rib, and last lumbar vertebra.
[4] Measured from first rib to point of aitch bone.
[5] Measured at seventh rib.
[6] U.S.D.A. grades for pork carcasses based on average back fat measurements and body length. (C-1=Choice No. 1, C-2=Choice No. 2, C-3=Choice No. 3.)

TABLE 3. SUMMARY OF STATISTICAL ANALYSIS [1]

Source		Average Daily Gain to 100 Pounds	Average Daily Gain to Slaughter	Hemoglobin	Dressing Percentage	Back Fat Thickness	Carcass Length	Carcass Depth
	d.f.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.	m.s.
Lots	5	.0039	.0040	.15	1.66**	.0089	.019	.129
Protein	2	.0003	.0018	.28**	1.45*	.0067	.031	.065
Aureomycin	1	.0080	.0067	.08	.90	.0204	.001	.058
Prot. x Aureo.	2	.0050	.0050	.01	2.25**	.0054	.014	.222
Within [2]	46	.0095	.0043	.05	.42	.0062	.117	.088

[1] Analysis of variance using the method described by Snedecor for disproportionate subclass numbers.
[2] Degrees of freedom were two less for dressing percentage, back fat thickness, carcass length, and carcass depth.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

respectively. The differences were not significant indicating that 14.3 percent of protein in the absence of aureomycin was just as suitable for weight gains as the higher levels. Catron *et al.* (1952) has reported that in the absence of antibiotic, 16 percent protein was satisfactory from weaning to 75 pounds. The animals used by Catron *et al.* were considerably smaller initially than those used in this study. Thus, these results tend to substantiate those reported by the Iowa workers. Similarly, Hoefer *et al.* (1952) obtained about the same growth on a 15 percent protein ration as on an 18 percent ration.

When aureomycin was added to the rations the gains for the low, intermediate, and high protein level groups, respectively, were 1.17, 1.13, 1.09. The antibiotic did not improve gains significantly at any protein level. It is difficult to explain the lack of antibiotic response. As shown in table 2, gains for the entire feeding period followed about the same trend as those up to 100 pounds. There were still no significant differences between any of the 6 experimental groups. It is interesting to note, however, that the best gaining group received the low protein ration plus aureomycin.

Feed Per Pound Gain

The low, intermediate, and high protein groups without aureomycin required 3.64, 3.06, and 3.72 pounds of feed per pound gain, respectively. These figures indicate a definite advantage for the 16 percent protein ration. Pigs on the high level protein ration were observed to scour considerably during the first three weeks of the test. This may be a partial explanation for the rather high feed conversion figure of 3.72 pounds for this group of pigs. When aureomycin was added the figures were 3.58, 3.10, and 3.40 for the low through the high protein levels, respectively. Aureomycin improved feed efficiency noticeably only on the high level protein ration.

Hemoglobin

Pigs that received the higher protein levels (17.6 and 20.9) averaged significantly higher in hemoglobin than those that received 14.3 percent of protein (table 2). Hemoglobin values were not significantly altered by aureomycin supplementation, although the pigs that received antibiotic were slightly higher in hemoglobin at all protein levels. This would tend to confirm the results of Cunha *et al.* (1950), who noted a small but consistent increase in hemoglobin when aureomycin was added to a corn-peanut meal ration.

Effect on Carcass

Dressing percentages were calculated from a warm carcass weight with head on and leaf fat in. The figures (table 2) show a higher dressing percentage for the low and high protein groups when aureomycin was included in the rations. The reverse was true at the intermediate level. The differences were not statistically significant. There was a significant difference in dressing percentage between the protein levels. Pigs that received the high protein level dressed significantly lower than pigs fed the other levels of protein. This appeared to be a clear reflection of carcass fatness as shown by backfat thicknesses (table 2).

The addition of aureomycin to the low, intermediate, and high protein rations resulted in increases in average backfat thickness of 0.15, 0.00, and 0.20 inches, respectively. These values approached significance at the five percent level. The matter of antibiotic effect on carcass fatness is a point of considerable controversy. These results would tend to confirm those of Bowland *et al.* (1951), who reported an increase in carcass fatness when a 15 percent ration was supplemented with aureomycin and B_{12}, but would not be in agreement with those of Vohs *et al.* (1951), Catron *et al.* (1952) and Wilson *et al.* (1953). The latter investigators have all reported that carcass fatness was not altered by antibiotic supplementation.

None of the dietary regimes affected carcass length or carcass depth significantly.

U.S.D.A. carcass grades, as shown in table 2, indicated that the most desirable carcasses were produced on the high level of protein without antibiotic. The average grade based on the average backfat thickness and average length was Choice No. 1 for this lot and Choice No. 2 for all other lots.

Summary

A combination feeding trial and slaughter experiment involving 54 pigs was conducted to determine the effect of aureomycin on protein requirement and to determine the effect of aureomycin and protein level on certain carcass measurements.

The results of the experiment indicate that a corn-soybean oil meal ration well fortified with mineral and vitamins and containing 14.3 percent of crude protein was just as satisfactory for weight gains of healthy weanling pigs fed in drylot as rations containing 17.6 and 20.9 percent of crude protein.

There was no clear evidence that aureomycin enhanced protein utilization.

Carcass studies indicated an increase, but not statistically significant, in backfat thickness as a result of aureomycin supplementation. Dressing percentages averaged slightly higher for the pigs that received the antibiotic and were significantly greater on the low and intermediate protein levels than on the high protein level. Carcass grades revealed an advantage for the group of pigs that received the high level of protein with no antibiotic added.

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THE INFLUENCE OF CRYSTALLINE AUREOMYCIN AND VITAMIN B_{12} ON THE PROTEIN UTILIZATION OF GROWING-FATTENING SWINE [1]

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VARIOUS workers (Keith and Miller, 1939, 1940; Carroll *et al.* 1939; Mitchell, 1939; and Crampton *et al.*, 1941–42) have suggested the protein requirement of swine represented by the approximate weight classes of weaning to 75 pounds, 76–125 pounds, and 126–200 pounds, to be 22–26, 16–20, and 12–15 percent crude protein respectively. Later work by Burnside *et al.* (1949) and Cunha *et al.* (1950) showed that an APF concentrate containing aureomycin and vitamin B_{12} was instrumental in increasing the efficiency of an all-plant ration fortified with seven crystalline B-vitamins as measured by rate and efficiency of gain. Their experiments suggest that the crude protein requirement of weanling pigs could be reduced from 20 percent to 18 percent. It is interesting to note that Cunha *et al.* (1950) and Catron *et al.* (1952) suggest that the addition of aureomycin to swine rations makes possible a 2 percent reduction in the protein content; however, they do not agree on the absolute amount of protein which must be present.

The purpose of this investigation was to study the effect of vitamin B_{12} and aureomycin, singularly and in combination, on the protein utilization of pigs from weaning to market weight when fed an all-plant ration. The criteria used were (a) efficiency and rate of gain, (b) hemoglobin values, (c) plasma protein values, and (d) digestibility coefficients.

Experimental Procedure

Ninety-six weanling pigs were stratified according to sex and randomized into 12 lots containing eight pigs each (four males and four females). The animals were housed on concrete, received feed and water *ad libitum*, and were weighed at weekly intervals.

The ration consisted of ground yellow corn, soybean oil meal, and

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7 percent dehydrated alfalfa leaf meal. The first two ingredients were adjusted to give the desired protein content. The trace mineralized salt contained 0.03 percent Cu as $CuSO_4$, 0.48 percent Mn as $MnSO_4 \cdot H_2O$, 0.01 percent Co as $CoCO_3$, 0.20 percent Fe as $FeC_6H_5 \cdot 5H_2O$, 0.007 percent I as KI which was stabilized with $Na_2S_2O_3$. Crystalline vitamin B_{12} and crystalline aureomycin [4] were added to the rations at a level of 20 gammas and 20 milligrams per kilogram of air dry ration respectively.

The treatments within each protein level were as follows: basal ration, basal ration plus B_{12}, basal ration plus aureomycin, and basal ration plus a combination of B_{12} and aureomycin. The rations were formulated to give a high, intermediate, and low protein level. As the average weight of each individual lot of pigs reached 70 and 125 pounds the protein content of the ration was revised downward and blood and fecal samples were taken from each pig. The crude protein content [5] of the various rations follows:

Period	High	Medium	Low
	%	%	%
Initial to 70 lb.	21.0	17.0	12.6
71 to 125 lb.	18.2	13.7	10.4
126 to 213 lb.	15.0	11.5	9.8

Seeley (1945), working with dogs, correlated total plasma protein values with N-balance studies. He found that a positive N-balance was necessary for plasma protein regeneration, the degree of regeneration depending on the degree of positive N-balance. Thus plasma protein regeneration is an index of protein utilization. The total plasma protein, albumin, and globulin was determined by the method of Kingsley (1942). In addition to the effect of treatment on protein utilization, the correlation between average daily gain and regeneration of plasma proteins and hemoglobin synthesis was also studied.

The influence of treatment on digestibility of the ration and of the protein in the ration was determined from fecal samples by the chromic oxide technique of Schurch *et al.* (1950). Four days before each protein revision and final weigh-off 1 percent chromic oxide was thoroughly mixed with the ration and the pigs allowed to consume this mixture for 4 days. On the evening of the fourth day or the morning of the fifth day a pint of fecal material was obtained

[4] The crystalline aureomycin and B_{12} were supplied by Lederle Laboratories and Merck and Company respectively.

[5] Analyzed according to A.O.A.C. (1945).

from each pig and immediately frozen. The three digestion coefficients for each pig were in close agreement and were pooled for the statistical analysis.

In the following data the 11 degrees of freedom between lots permit only 11 valid comparisons to be made with the given LSD values. Thus the treatments within each protein level were compared with their respective basal ration and the treatment giving the best results in the medium and low protein groups was compared to the high protein basal ration.

Results

Effect of Treatment on Rate of Gain

First Period—Initial to 70 Pounds. Table 1 gives a summary of the performance of the pigs on all treatments during the three periods. Table 2 summarizes the gains from initial to final weight. This period is hereafter referred to as the fourth period.

The addition of aureomycin significantly increased the rate of gain at all protein levels, whereas the combination of aureomycin and B_{12} significantly increased the rate of gain only in the high and low protein groups. Supplementation of the basal rations with vitamin B_{12} resulted in a significant increase in rate of gain only in the low protein group. An additional 0.05 of a pound was needed for a significant difference in the B_{12} medium protein lot.

The rate of gain of the aureomycin lot of pigs in the medium protein group was significantly higher than the rate of gain of the basal lot of pigs in the high protein group. When the rate of gain of the aureomycin-B_{12} lot in the low protein group was compared to the gains made by the basal lot of pigs in the high protein group, no significant difference was found.

Second Period—71 to 125 Pounds. The supplementation of each of the basal rations with aureomycin significantly increased the rate of gain only in the high and medium protein groups. The combined treatment produced a significant increase in average daily gains of the animals in the medium and low protein groups only. When vitamin B_{12} was added to the three basal rations, a significant increase in rate of gain was not observed for any of the protein groups.

Aureomycin treatment in the medium protein group resulted in weight gains which did not differ significantly from those made by the animals on the high protein basal ration. In the low protein group, the combined treatment gave the most rapid gain in weight; however,

TABLE 1. SUMMARY OF GROWTH DATA FOR FIRST THREE PERIODS

Item	Period	High Protein Ration				Medium Protein Ration				Low Protein Ration			
		Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.	Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.	Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.
No. pigs in lot	1–3	8	8	8	8	8	8	8	8	8	8	8	8
Level of protein, %		20	20	20	20	16	16	16	16	12	12	12	12
No. days in period		26	22	19	20	21	22	18	18	26	25	21	25
Av. initial wt., lb.		41.9	45.4	44.9	42.3	45.5	43.5	47.9	42.2	45.5	45.0	43.6	44.4
Av. final wt., lb.	1	69.7	70.4	72.1	72.6	70.8	72.0	73.0	67.5	64.9	68.0	65.9	72.0
Av. da. gain, lb.		1.12	1.12	1.42**	1.55**	1.18	1.32	1.32	1.45*	0.72	0.91*	1.07**	1.10**
Av. da. feed, lb.		3.10	3.22	3.95	3.75	3.57	3.95	4.17	4.03	3.19	3.50	3.57	3.88
Feed per cwt. gain, lb.		290.3	283.8	276.5	247.9	296.3	305.2	298.5	287.1	427.7	380.4	337.1	351.1
Level of protein, %		17	17	17	17	13	13	13	13	10	10	10	10
No. days in period		36	38	31	36	41	39	31	35	69	60	50	50
Av. final wt., lb.	2	126.0	127.3	123.9	123.6	127.1	126.6	124.1	125.8	127.0	125.4	124.5	126.5
Av. da. gain, lb.		1.54	1.49	1.63	1.37*	1.36	1.36	1.59*	1.71**	0.99	1.01	1.24*	1.05
Av. da. feed, lb.		5.49	5.46	5.05	4.51	5.27	5.46	5.44	5.49	4.29	4.61	5.65	5.34
Feed per cwt. gain, lb.		351.2	364.2	302.1	218.1	384.6	389.9	330.0	330.2	476.1	482.4	482.2	490.3
Level of protein, %		14	14	14	14	11	11	11	11	9.5	9.5	9.5	9.5
No. days in period		47	45	45	53	54	58	49	45	77	69	59	66
Av. final wt., lb.	3	213.9	214.2	212.6	213.2	213.6	212.3	217.8	212.4	213.6	213.6	213.6	213.1
Av. da. gain, lb.		1.86	1.91	1.99	1.71	1.59	1.47	1.92*	1.93*	1.11	1.26	1.52**	1.30
Av. da. feed, lb.		7.76	7.82	8.09	6.77	7.05	7.14	7.24	7.34	5.78	6.45	6.89	6.32
Feed per cwt. gain, lb.		414.9	405.0	410.4	400.6	440.0	483.4	378.5	381.0	514.1	504.5	456.4	481.8

* Significant at 5% level.
** Significant at 1% level.

LSD at 5% level for av. da. gain is 0.19, 0.21, and 0.29 lb. for the first, second, and third period respectively, at the 1% level it is 0.25, 0.28, and 0.39 lb. for the first through third period respectively.

TABLE 2. SUMMARY OF GROWTH DATA FOR THE FOURTH PERIOD INCLUDING DIGESTIBILITY COEFFICIENTS

Item	Period	High Protein Ration				Medium Protein Ration				Low Protein Ration			
		Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.	Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.	Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.
No. pigs in lot		8	8	8	8	8	8	8	8	8	8	8	8
No. days on exp.		109	105	95	109	116	119	98	98	172	154	130	141
Av. initial wt., lb.		41.9	45.4	44.9	42.3	45.5	43.5	47.9	42.2	45.5	45.0	43.6	44.4
Av. final wt., lb.		213.9	214.2	212.6	213.2	213.6	212.3	217.8	212.4	213.6	213.6	213.6	213.1
Av. da. gain, lb.		1.62	1.59	1.75	1.60	1.43	1.43	1.67	1.78**	0.96	1.09	1.32**	1.20
Av. da. feed, lb.		5.90	6.00	6.27	5.47	5.79	6.00	6.10	6.07	4.79	5.26	5.88	5.54
Dig. of ration, %	4	72	72	76*	70	73	70	73	75	77	73*	74	77
Dig. of protein in ration, %		66	68	74**	70	60	59	68**	68**	62	52**	60	64
Feed per cwt. gain, lb.		373.9	373.3	355.2	348.9	399.7	423.1	352.1	349.7	490.1	480.0	449.7	463.1
Cost of feed per cwt. gain. Cost of B_{12} and aureomycin not included		$11.13	$11.11	$10.56	$10.37	$11.40	$12.07	$10.40	$ 9.98	$13.58	$13.30	$12.46	$12.84

* Significant at 5% level.
** Significant at 1% level.

LSD for av. da. gain at 1% and 5% is 0.35 and 0.26 lb. respectively. LSD for dig. of ration is 3.5 and 4.7 for the 5% and 1% level respectively, for the dig. of protein in the ration the LSD is 5 and 6.7 for the 5% and 1% level respectively.

this rate of gain was still significantly lower than the weight gain recorded for the basal lot of pigs in the high protein group.

Third Period—126 to 213 Pounds. In this period, aureomycin supplementation of the basal rations significantly stimulated the rate of gain only in the medium protein group, whereas the combined treatment, when compared with the appropriate basal rations, gave a significant increase in rate of gain only in the medium and low protein groups. Again, the B_{12} treatment has no significant effect on the rate of gain in any of the protein groups.

The stimulatory effect of aureomycin on rate of gain was such that the weight gain of the aureomycin lot of pigs in the medium protein group did not differ significantly from the weight gain made by the high protein control animals. The rate of gain made by this latter lot of pigs was significantly higher than the rate of gain recorded for the B_{12}-aureomycin in the low protein group.

Fourth Period—Initial weight to 213 pounds. The results of this period show that in the high protein group the various supplementations to the basal ration did not result in a significant difference in the rate of gain when compared to the rate of gain recorded for the basal ration alone.

In the medium protein group, aureomycin supplementation of the basal ration was the only treatment which gave a rate of gain that was significantly faster than that recorded for the basal lot. In the low protein group B_{12} plus aureomycin was the best supplement; in fact, it was the only one that increased the rate of gain above that of the basal lot of pigs significantly.

The data from these four periods suggest that the medium protein basal ration, when supplemented with aureomycin, is as efficient for growing-fattening pigs as the higher protein ration similarly supplemented.

In the low protein group, B_{12} appeared to be of more help than in the other two groups. The combined treatment in this group gave better results than did either treatment alone, showing that at this protein level the B_{12} content of the ration became critical. Although a sparing of protein is suggested by the combined treatment, the amount of protein actually present in the low protein rations is not sufficient to produce gains which are equal to those obtained in the medium protein basal lot. However, the increase in rate of gain due to supplementation of the low protein basal ration and medium protein basal ration with B_{12}-aureomycin and aureomycin respectively is of the same magnitude, i.e., 0.36 of a pound.

Effect of Treatment on Feed Utilization

Table 3 shows the effect of each treatment on feed efficiency as measured in percent increase or decrease when contrasted to its respective control.

In the first period there is little or no change in feed efficiency between the basal lots in the high and medium protein group. In the second and third periods the basal lot of the high protein group was 10 and 6 percent respectively more efficient in converting feed

TABLE 3. EFFECT OF TREATMENT ON FEED EFFICIENCY, IN PERCENT, WHEN COMPARED WITHIN PROTEIN LEVELS TO CORRESPONDING BASAL RATIONS

Ration	Period	Basal	Basal + B_{12}	Basal + B_{12} + Aureo.	Basal + Aureo.
			(% difference from basal)		
High protein	1	290 [1]	2	5	14
	2	351	−4	14	9
	3	415	2	2	3
	4	374	0	5	7
Medium protein	1	296	−3	0	3
	2	349	−1	14	14
	3	440	−10	14	14
	4	400	−6	12	12
Low protein	1	428	12	21	18
	2	476	−1	−1	−3
	3	514	2	11	6
	4	490	2	8	6

[1] Pounds of feed per cwt. gain.

to body tissue than the corresponding lot in the medium protein group. From the initial weight to the final weight the basal lot in the high protein group was 6 percent more efficient in their use of feed than was the control of the medium protein group. The medium and low protein basal lots required 6, 33, 25, and 137, 125, 99 pounds more feed per 100 pounds of gain for the first, second, and third period respectively than did the high protein basal lot. This trend suggests that the low protein level is becoming less critical as the pigs in this group reach heavier weights and that the medium protein levels are becoming a trifle more acute.

Although the feed efficiency data in table 3 show a varied response for a particular lot and period, two definite trends are indicated.

Vitamin B_{12} is detrimental when added to the medium protein ration, and in the low protein group all of the treatments have a small depressing effect on feed efficiency during the second phase.

In the high protein group during the first period, aureomycin was instrumental in increasing the feed efficiency; this effect was observed in the next two periods but to a lesser degree which was partially in keeping with the effect aureomycin had on the rate of gain in this particular protein group. After the first period there was very little difference between the feed efficiency of the lot receiving the combination supplement as contrasted to the aureomycin lot. Vitamin B_{12} was of little or no help in increasing feed efficiency.

Aureomycin alone or in combination with B_{12} gave essentially the same results in the medium protein group. It was only during the first period that aureomycin seemed to exert more of an influence on feed efficiency than did the combination treatment. There was no difference in the effect of aureomycin alone or in combination with B_{12} when considered from the initial weight to the final weight.

In the low protein group, B_{12} was beneficial during the first period and to a lesser extent in the third period. Aureomycin and B_{12} appear to have a greater effect on feed efficiency than does aureomycin alone, the most pronounced effect being in the third period. Considering these data from initial weight to final weight, B_{12} had little effect; most of the effect was present during the first period. The combination of treatments has more of an effect on the feed efficiency than does either alone.

Except for the low protein group, the feed efficiency data follow the same general trend suggested by the digestion coefficients, the coefficients for protein digestibility being in somewhat closer agreement with feed efficiency than the dry matter coefficients. The values recorded for the aureomycin and aureomycin-B_{12} lots in the high protein group and the B_{12} lot in the medium protein group appear more variable than would be anticipated on the basis of the feed efficiency data.

The detrimental effect of B_{12} on feed utilization in the medium protein group is unexplainable as are the negative results obtained for all treatments in the second period of the low protein group.

Effect of Treatment on Hemoglobin Synthesis

First Period—Initial to 70 Pounds. The blood data are presented in table 4.

TABLE 4. SUMMARY OF BLOOD DATA BY PERIODS

Item	Period	High Protein Ration				Medium Protein Ration				Low Protein Ration				LSD .05	LSD .01
		Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.	Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.	Basal	Basal+ B_{12}	Basal+ B_{12}+ Aureo.	Basal+ Aureo.		
Hemoglobin gm./100 ml. blood	1	10.99	10.60	11.96**	11.21	10.87	10.55	11.18	11.35	10.80	10.72	10.59	10.96	0.69	0.91
	2	12.52	13.00	13.72*	11.88	11.89	12.58	13.13*	12.98*	10.78	11.01	11.06	11.00	0.96	1.27
	3	13.68	13.59	13.97	12.66*	12.43	12.98	14.10**	13.38*	11.66	11.63	13.38**	11.82	0.82	1.09
	Av.	12.40	12.40	13.22	11.92	11.73	12.04	12.80	12.57	11.08	11.12	11.68	11.26		
Total Prot. gm./100 ml. plasma	1	6.49	6.90*	6.97*	7.18**	6.85	6.67	6.89	7.02	5.56	6.01*	6.06*	6.06*	0.39	0.52
	2	6.74	7.12**	7.65**	7.12**	6.81	6.86	7.77**	7.52**	4.48	5.22**	5.85**	5.56**	0.29	0.38
	3	9.13	8.93	8.97	8.65**	8.07	8.24	9.05**	9.15**	4.77	5.20*	6.92**	5.78**	0.35	0.46
	Av.	7.45	7.65	7.86	7.65	7.24	7.26	7.90	7.90	5.08	5.48	6.28	5.80		
Albumin	1	2.97	3.76**	3.65**	3.95**	3.87	3.55	3.49*	3.29**	2.15	3.30**	3.34**	2.68**	0.45	0.34
	2	3.61	3.57	3.86	3.88	3.34	3.29	3.52	3.67	2.47	2.48	2.66	2.64	0.37	0.49
	3	4.42	4.33	4.71	4.38	3.99	4.10	4.55*	4.52*	2.43	2.87	3.25**	3.36**	0.45	0.59
	Av.	3.67	3.89	4.07	4.07	3.73	3.65	3.85	3.83	2.35	2.88	3.08	2.89		
Globulin	1	3.49	3.15	3.32	3.21	3.00	3.11	3.44*	3.71**	3.41	3.72	2.71**	3.39	0.43	0.58
	2	3.14	3.55**	3.80**	3.25	3.47	3.57	4.23**	3.85**	2.01	2.74**	3.19**	2.92**	0.24	0.31
	3	4.71	4.60	4.26	4.28	4.09	4.14	4.49	4.63	2.34	2.35	3.67**	2.42	0.56	0.74
	Av.	3.78	3.77	3.79	3.58	3.52	3.62	4.05	4.06	2.59	2.94	3.19	2.91		

* Significant at 5% level.
** Significant at 1% level.

The only significant difference in the hemoglobin values was in the high protein group. The supplementation of the high protein basal ration with B_{12} and aureomycin stimulated hemoglobin synthesis significantly above that observed for the basal lot of pigs.

Second Period—71 to 125 Pounds. Aureomycin supplementation of the three basal rations significantly increased hemoglobin synthesis only in the high protein group. The combination of B_{12} and aureomycin was instrumental in stimulating hemoglobin synthesis to a significant degree only in the high and medium protein groups.

The average hemoglobin values recorded for the high protein basal ration and the medium protein B_{12} plus aureomycin lot did not differ significantly, but the rate of hemoglobin synthesis observed for this latter treatment in the low protein group was significantly lower than that observed for the high protein basal lot.

Third Period—126 to 213 pounds. The addition of aureomycin singly or in combination with vitamin B_{12} significantly increased the rate of hemoglobin synthesis in the medium protein group. In the low protein group a significant stimulatory effect on the rate of hemoglobin synthesis was noticed only when the basal ration was supplemented with B_{12} and aureomycin.

Contrary to these observations, hemoglobin synthesis by the pigs receiving aureomycin in the high protein group was significantly lower than that of the animals in the basal lot.

Supplementation of the three basal rations with vitamin B_{12} did not significantly alter the hemoglobin values in any of the three protein groups.

Hemoglobin for the basal lot in the high protein group did not differ significantly from that of the B_{12} plus aureomycin lot in the medium and low protein groups.

Some significant differences were noted in the effect of treatment on hemoglobin synthesis, but the correlation recorded for the between treatment hemoglobin values and rate of gain was not significant. For all practical purposes the hemoglobin values are within the normal range, i.e., 11–14 grams of hemoglobin per 100 milliliters of blood. The average hemoglobin value for this experiment was 12.01 which agrees with the generally accepted average value of 11.95.

Effect of Treatment on Plasma Protein Regeneration

First Period—Initial to 70 Pounds. The total plasma protein values are recorded in table 4.

All supplementations of the high and low protein basal rations stimulated plasma protein regeneration significantly; in contrast to this, none of the supplementations of the medium protein basal ration changed significantly the rate of plasma protein regeneration.

The plasma protein value recorded for the medium protein aureomycin lot was significantly higher than the value recorded for the control lot in the high protein group; conversely to this, plasma protein regeneration by the animals in the B_{12} plus aureomycin lot in the low protein group was significantly lower than that of the latter group.

Second Period—71 to 125 Pounds. Again, all supplementations of the high and low protein basal rations stimulated plasma protein regeneration significantly. Unlike the first period, the addition of vitamin B_{12} alone or in combination with aureomycin to the medium protein basal ration increased significantly the rate of plasma protein regeneration.

Plasma protein regeneration by the animals in the medium protein aureomycin lot was significantly higher than that of the high protein basal lot, but the values for this latter lot were significantly higher than the plasma protein value for the B_{12} plus aureomycin in the low protein group.

Third Period—126 to 213 Pounds. In contradistinction to the other two periods, the various supplementations of the high protein basal ration did not increase the rate of plasma protein regeneration significantly; in fact, the rate of plasma protein regeneration observed in the aureomycin lot was significantly lower than that of the basal lot.

In the low protein group all of the various supplementations of the basal ration increased the rate of plasma protein regeneration significantly over that observed for the basal ration. This observation has been true for all three periods.

Aureomycin supplementation alone or in combination with B_{12} significantly stimulated the plasma protein regeneration in the medium protein group when contrasted to the basal ration. This is in agreement with the observations made in the second period.

When the medium protein basal ration was supplemented with vitamin B_{12}, the rate of plasma protein regeneration was not significantly altered.

The difference between the values recorded for the medium protein aureomycin lot and the high protein basal lot was not significant; however, the value recorded for the low protein aureomycin-B_{12} lot was significantly lower than the value recorded for the latter lot.

The stimulation of protein utilization by the use of aureomycin

alone or in combination with B_{12} is also clearly evident in these plasma protein values.

To the authors' knowledge this is the first report dealing with a decidedly detrimental effect of aureomycin in rations for swine. After the first period in the high protein group, aureomycin caused a decrease in rate of gain and hemoglobin values, but it was only after the second period that the total plasma protein value was decreased. This trend was not observed for the medium protein group in any of the criteria used. It would appear that on the high protein ration, aureomycin has influenced the flora in such a way as actually to make less nutrients available instead of more; it would further appear that B_{12} was the limiting factor involved in that vitamin B_{12} complements the aureomycin to a noticeable degree in the second and third period, but regardless of period, it was of no benefit when added to the basal ration alone. Halick and Couch (1951) have observed a similar effect in that aureomycin or penicillin assisted in the depletion of B_{12} or possibly B_{12} and unidentified factors in the chick.

These data suggest that when a weight of about 70 pounds is reached, aureomycin supplementation accentuates the need for B_{12} either by eliminating a group of microorganisms that are synthesizing small quantities of B_{12} and do not require it, or that it increased another group of organisms which require B_{12} but could not synthesize it and consequently competed with the host for the available dietary supply. Whatever the mode of action, the regeneration of plasma protein seemed to be less affected than the rate of gain or hemoglobin synthesis. Why this effect is noted only in the high protein group is difficult to explain.

The Effect of Treatment on Digestibility of the Ration and of Protein in the Ration

Effect on Ration. The coefficients for digestibility of dry matter are about 4 percent lower than the figures reported by Schurch *et al.* (1952). There was no difference in the digestibility of the ration for the medium protein group, but the coefficient of digestibility for the aureomycin-B_{12} lot in the high protein group is significantly higher than the value for the basal lot. In the low protein group the same trend is apparent in the values recorded for digestion of the ration as well as digestion of the protein in the ration. Under the conditions of this experiment, the digestion coefficients of the ration are not a good indication of the rate of gain.

Effect on Protein in Ration. Supplementation of the three basal rations with vitamin B_{12} gave no significant differences in protein digestibility in the high and low protein groups. In the low protein group the protein of the basal ration was digested to a significantly higher degree than was the protein of B_{12} supplemented ration.

The combination treatment in the high and medium protein groups resulted in an increase in protein digestibility which was highly significant; no difference was noted in the low protein group.

Aureomycin supplementation of the medium protein basal ration resulted in a significant increase in protein digestibility, the magnitude of increase being the same as that observed for the combination treatment in the same protein group.

The digestibility coefficients for the basal lot of the high protein group and the aureomycin lot of the medium and low protein groups did not differ significantly from each other. The protein digestibility coefficients for the aureomycin treatments did not differ a great deal from those obtained with aureomycin-B_{12} supplementation. However, it is noted that in the high protein aureomycin lot the trend for digestibility of the ration and protein in the ration closely follows that suggested by the effect of aureomycin on gains from 71 to 213 pounds. Attention is called to the high digestibility coefficients registered for the low protein basal ration.

Within each protein level the protein digestion coefficients of the treatment groups are in close agreement with the gains and blood data, and offer further evidence as the stimulatory effect of aureomycin on protein utilization in swine. The one exception is found in the protein digestion coefficient for the low protein basal lot. This value is exceptionally high and is out of line with the rest of the values for the low protein ration. The protein coefficient for the low protein B_{12} lot is significantly lower than the digestion coefficient for the basal lot but the remaining values do not differ significantly.

Correlation and Regression of Blood Data on Average Daily Gains

Hemoglobin on Average Daily Gains. Table 5 shows that under the condition of this experiment there exists a strong positive correlation between rate of gain and hemoglobin content of the blood. Of particular interest is the correlation between hemoglobin and rate of gain within lots for a particular period; a similar correlation exists between lots for a given period.

Table 5 also shows that a strong correlation exists between hemo-

TABLE 5. CORRELATIONS AND REGRESSIONS OF AVERAGE DAILY GAINS ON BLOOD DATA

Association	Gain on Hemoglobin		Gain on Total Plasma Protein		Gain on Globulin		Gain on Albumin	
	r	b	r	b	r	b	r	b
Gross	.7176**	2.30	.6684**	2.01	.2529**	0.49	.7898**	1.52
Between lots for a particular period	.8937	3.15	.9104**	3.56	.7546**	1.62	.8867**	1.94
Within lots for a particular period	.1411*	1.18	.2172**	0.26	—.4794**	—0.79	.6639**	1.05
Between protein levels for the 3 periods combined	.9981**	2.74	.9991**	4.46	.9880*	1.90	.9991**	2.56
Within protein levels for the 3 periods combined	.2049**	2.17	.4794**	1.23	.0202	0.40	.7116**	1.19
Between treatments for the 3 periods combined	.8754	2.32	.9902**	2.96	.9643**	1.34	.9931**	1.62
Within treatments for the 3 periods combined	.2247**	2.31	.6487**	1.95	.2228**	0.44	.7640**	1.52
Between periods for the twelve lots	.9692**	4.12	.9075	2.81	.9223	1.25	.9200	1.57
Within periods for the twelve lots	.2057**	1.92	.6121**	1.83	.1591**	0.32	.7665**	1.51

* Significant at 5% level.
** Significant at 1% level.
r is correlation coefficient.
b is regression coefficient.

globin values and rate of gain within a particular treatment over the three periods.

The correlation recorded for the between treatment hemoglobin values and rate of gain was not significant. For all practical purposes the hemoglobin values are within the normal range, i.e., 11–14 grams of hemoglobin per 100 milliliters of blood. The average hemoglobin value for this experiment was 12.01 which agrees with the generally accepted average value of 11.95.

Plasma Protein on Average Daily Gain. There exists a strong correlation between total plasma protein, albumin, globulin, and rate of gain when considered within lots and between lots for a particular period as well as within treatments and between treatments over the three periods. Of particular interest is the correlation of plasma protein and rate of gain between the three protein levels and between treatments over the three periods. This latter correlation was not significant for the hemoglobin values.

The correlation between the globulin values and average daily gains presents quite a different story in that a highly significant negative correlation is evident. The normal situation in the pig is for the two values to be equal or the globulin tends to be slightly in excess of the albumin. The rate of gain seems to have a modifying influence on this ratio especially under the extreme conditions of the low protein ration.

The strong correlation of plasma protein values with average daily gain, and the fact that they are more sensitive than hemoglobin values in reflecting the extent of protein utilization should prove useful in future experiments, particularly in experiments dealing with protein utilization.

Under the conditions of this experiment, the protein sparing of aureomycin makes possible the feeding of a 17, 13.7, and 11.5 percent crude protein ration to swine of the weight classes of weaning to 70, 71 to 125, and 126 to 213 pounds. These results are in agreement with the six weeks' study of Cunha *et al.* (1950) but are only in partial agreement with the results of Catron *et al.* (1952).

Summary

Data have been secured to determine the effect of crystalline vitamin B_{12} and crystalline aureomycin on the protein utilization of growing-fattening swine when they were fed rations consisting of corn, soybean oil meal, alfalfa meal, and minerals. These rations were fed at three

levels of protein to 12 lots of eight pigs each. The lots within each protein level consisted of the basal ration, basal plus B_{12}, basal plus B_{12} plus aureomycin, and basal plus aureomycin. The initial crude protein contents of the rations were 21 percent, 17 percent, and 12.6 percent. When each lot averaged 70 pounds, the protein content was lowered to 18 percent, 13.7 percent, and 10.4 percent respectively; and again when each lot averaged 126 pounds, to 15 percent, 11.5 percent, and 9.8 percent respectively. The pigs were removed from the experiment as each lot averaged 213.0 pounds. Vitamin B_{12} and aureomycin were mixed in the ration at the rate of 20 gammas and 20 milligrams per kilogram of ration respectively. Blood and chromic oxide fecal samples were taken from each pig on the day of the protein change and on the day the lot averaged 213.0 pounds. Hemoglobin, total plasma protein, albumin, and globulin were determined on the blood, and digestibility coefficients for the ration and protein in the ration were determined from the fecal samples.

Vitamin B_{12} was of little or no help in increasing rate of gain, feed efficiency, hemoglobin, total plasma protein, or digestibility. Aureomycin alone was of no help to the high protein pigs after a weight of 70 pounds was reached, however, the performance of the other lots was increased as judged by the above criteria. Aureomycin alone or in combination with B_{12} increased the protein utilization of pigs to the extent that rations containing 17 percent, 13.7 percent, and 11.5 percent protein were equal to rations containing 21 percent, 18.2 percent, and 15.0 percent under the same conditions.

A number of significant correlations of gains with blood data was found.

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ANTIBIOTIC SUPPLEMENTATION OF CORN-COTTONSEED MEAL RATIONS FOR GROWING PIGS

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THERE has appeared in recent years a great volume of literature on the use of antibiotics in swine rations. Many different protein feeds have been used in these studies. However, there appears to be only a limited literature on the effect of antibiotics as supplements to corn-cottonseed meal rations.

Dyer *et al.* (1950) reported that aureomycin and streptomycin stimulated the growth of pigs receiving a corn-cottonseed meal ration. The work of Barrick *et al.* (1950) also indicated a stimulating effect for aureomycin. Some growth response to supplementation of a corn-cottonseed meal ration with streptomycin and penicillin was reported by Bridges *et al.* (1951). In a later report Bridges *et al.* (1953) stated that a significant growth stimulation was produced by a combination of penicillin and streptomycin but these two antibiotics failed to produce a significant increase in growth when used individually. Wallace *et al.* (1953) reported that withdrawal of aureomycin from a corn-cottonseed meal ration when pigs reached 150 pounds resulted in a reduced rate of gain and reduced efficiency of feed conversion.

The lack of appreciable information on the value of antibiotics in cottonseed meal rations might be attributed to the frequently encountered toxic effect of cottonseed meal. The work of Barrick *et al.* (1950) and Fletcher (1948) showed that this toxicity could be avoided by inclusion of ferrous sulfate in the ration. This technique for the prevention of toxicity was utilized in a series of experiments conducted to determine the effect of supplementing corn-cottonseed meal rations with certain antibiotics.

Experimental

Five dry lot feeding experiments involving 94 pigs were conducted. The pigs used in these experiments had a good nutritional history and were in thrifty condition at the start of the feeding periods. In alloting the pigs to the various treatment groups they were stratified as to breed and litter. Random allotment was then used within each stratum.

Two slightly different basal rations were used. These rations are

shown in table 1. Basal ration A was used in experiments I and II and Basal B in experiments III, IV and V. The basal rations were supplemented with fermentation products having either aureomycin or penicillin potency. Both antibiotic supplements contained B_{12}. The aureomycin supplement contained 2 mg. of B_{12} and the penicillin supplement 3 mg. of B_{12} per pound. Therefore it is possible that the growth responses noted might have been in part the result of the vitamin B_{12} present. The aureomycin supplement was added in amounts sufficient to supply either 6.8 or 13.6 mg. of aureomycin per pound of ration. The penicillin supplement used provided only 2 mg. of penicillin per pound of ration.

TABLE 1. COMPOSITION OF THE BASAL RATIONS

Ration	A	B
Ingredient	%	%
Corn	71.0	68.5
Cottonseed meal	25.0	25.0
Alfalfa meal	2.5	5.0
Salt	0.5	0.5
Oyster shell flour	0.5	0.5
Ferrous sulfate	0.5	0.5

The level of the antibiotics used in each experimental lot is shown in table 2.

Results

The average daily gains and average feed efficiencies secured in the five experiments are shown in table 2. There was considerable variation in the initial and final weights of the pigs in the different experiments. For that reason these two weights were included in the summary table. The average daily feed consumption for each lot was also included.

In experiment I there was a consistent response to the aureomycin as measured by daily gain, daily feed consumption and efficiency of feed conversion. The increase in daily gain from 1.42 pounds in the control lot to 1.58 pounds in the supplemented lot approached but failed to show significance on statistical test. The data on feed efficiency and daily feed consumption were not adapted to statistical test. The results in the second experiment were somewhat different. The data from this experiment indicated a response to aureomycin only when measured by feed required per pound of gain. Even this effect was noted only in the lot receiving 6.8 mg. of aureomycin per pound of feed. The 13.6 mg. level of aureomycin appeared to have a depressing effect on both rate

TABLE 2. THE EFFECT OF AUREOMYCIN AND PENICILLIN SUPPLEMENTATION ON GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY

Expt.	Lot	Number of Pigs	Ration	Average Initial Weight (lb.)	Average Final Weight (lb.)	Average Daily Feed (lb.)	Average Daily Gain (lb.)	Feed per cwt. Gain (lb.)
I	1	8	Basal A	43.2	183.7	6.37	1.42	449.2
	2	8	Basal A+6.8 mg. aureomycin/lb. feed	43.6	200.0	6.43	1.58	407.6
II	14	10	Basal A	73.0	165.4	7.68	1.84	423.8
	15	10	Basal A+6.8 mg. aureomycin/lb. feed	73.2	162.1	7.03	1.77	403.0
	16	10	Basal A+13.6 mg. aureomycin/lb. feed	73.2	155.9	7.68	1.65	473.5
III	1	6	Basal B	34.8	141.0	4.85	1.06	551.0
	2	6	Basal B+6.8 mg. aureomycin/lb. feed	35.4	170.8	5.03	1.35	449.9
	3	6	Basal B	49.4	189.4	4.98	1.32	370.8
	4	6	Basal B+6.8 mg. aureomycin/lb. feed	50.6	205.6	5.14	1.46	351.4
IV	5	6	Basal B	30.0	89.0	2.54	0.62	410.0
	6	6	Basal B+2 mg. penicillin/lb. feed	29.8	103.6	2.61	0.78	336.0
V	5A	6	Basal B	30.5	68.0	2.25	0.55	510.0
	6A	6	Basal B+2 mg. penicillin/lb. feed	31.7	77.9	2.27	0.64	443.6

and efficiency of gain. The effect on rate of gain was not found to be significant when subjected to statistical test.

The results of both replicates included in experiment III are shown in the summary table. Lots 1 and 2 made the first replicate and lots 3 and 4 the second. In this trial aureomycin supplementation increased feed consumption, daily gain and feed efficiency. Daily rate of gain was the only item suited to statistical test. The difference in rate of gain between the basal and supplemented lots approached but did not reach statistical significance.

Experiments IV and V might have been considered replicates although conducted at slightly different times. In view of the variation in feed efficiency observed in the two tests, the data are presented separately for the two experiments. In experiment IV a pig in lot 6 made quite poor growth. However it appeared that this pig had a low feed intake since the feed efficiency for lot 6 as a whole was very good. The lots receiving penicillin in both experiment IV and V exceeded the control lots in daily gain, feed consumption and efficiency of feed conversion. The increase in feed consumption was very slight and the increase in rate of gain not statistically significant. The level of penicillin fed, 2 mg. per pound of ration, was relatively low and it is possible that greater response might have resulted from a higher level of supplementation. The increase in efficiency of feed utilization was most striking and might well be considered significant although the experimental design did not permit this analysis.

Summary

Five dry lot group feeding experiments were conducted in which the value of certain antibiotic supplements to a corn-cottonseed meal ration were studied. In three experiments aureomycin was used and in two experiments penicillin was the antibiotic. Both aureomycin and penicillin supplementation appeared to increase feed consumption and the efficiency of feed utilization by growing pigs. Increases in daily rate of gain were secured in all except one of the comparisons made. These increases in rate of gain produced by aureomycin or penicillin supplementation of a corn-cottonseed meal ration were near but did not reach levels necessary for statistical significance.

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THE EFFECT OF FEEDING DIFFERENT LEVELS OF A CELLULOSIC MATERIAL TO SWINE [1]

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IT has been shown that for rapid and efficient gains the diet of growing and fattening pigs should not contain large amounts of fibrous material (Vestal, 1921; Evvard, 1929; and Robison, 1930). Even though the crude fiber portion of the diet fed to pigs during this period is commonly less than five percent, it has not been demonstrated what the physiological role of fiber in the pig may be nor is there agreement concerning the extent of its utilization.

The extreme variation of the reported coefficients of digestibility may be in part due to the source of fiber ingested as well as its physical and chemical condition as affected by previous treatment. Woodman and Evans (1947) included a fodder cellulose prepared by the treatment of wheat straw with caustic soda as 31.8 percent of the diet for pigs which weighed from 199 to 224 pounds at the beginning of the experiment. They found the apparent digestibility of the cellulose in the diet to be 82.1 percent. In contrast, other workers have found that the fiber fed to pigs was poorly utilized. Mitchell and Hamilton (1933) used paper pulp (cellomass) or cellophane to the extent of 8.05 percent of a purified diet and fed it to pigs maintained at weights of 168 to 185 pounds. Under these conditions, the two forms of cellulose were digested to the extent of 3.5 percent, on the average, with a range for individual pigs of 0.0 to 9.2 percent.

The physical characteristics of fiber may be important. Crampton and Bell (1946), in studying the effect of fineness of grinding on the utilization of oats by market hogs found that as the particle size became smaller significantly faster gains were obtained. These authors suggested the possibility that oat hulls contain one or several factors which affect the utilization of other dietary constituents.

In the present studies a prepared cellulose material, Ruffex, was used. This material is manufactured from rice straw. According to the manufacturer (Fisher Scientific Co.), Ruffex is free from proteins, fats and

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TABLE 1. COMPOSITION OF BASAL DIET

Components	Percentage Composition	
	Weaning to 100 Pounds	100 Pounds to 200 Pounds
Starch, corn	70	73
Casein, crude	15	12
Lard	3	3
Mineral mixture	6	6
Brewers' yeast*	6	6

* Anheuser-Busch, Strain G.

vitamins, and contains less than one percent total ash. Seventy percent of the material is said to be alpha cellulose and the remainder simple and hydrocelluloses. Ruffex was used to replace variable amounts of corn starch in a purified diet. The objectives of the study were to determine the effects of feeding different levels of this product on growth, on digestibility of the various nutrients in the diet, on feed utilization, and on carcass characteristics.

Experimental Procedure and Results

Experiment 1

Eight purebred Duroc barrows, farrowed in April or May, were weaned when from 30 to 48 days of age and placed on the control diet until the beginning of the experiment July 10, 1948. They were produced by littermate gilts which had been raised in strict confinement on concrete. The animals were allotted and fed individually in wooden floored indoor pens. Contents of the basal diet and mineral mixture are shown in tables 1 and 2.

TABLE 2. COMPOSITION OF MINERAL MIXTURE

Component	Percent
Monobasic calcium phosphate	35.0
Ground limestone (calcite)	20.0
Sodium chloride (feed grade)	20.0
Potassium chloride (U.S.P.)	10.0
Magnesium carbonate (U.S.P.)	8.0
Ferric citrate (U.S.P.)	6.0
Manganese sulfate (Reagent)	0.5
Copper sulfate (C.P.), anhydrous	0.2
Zinc oxide (U.S.P.)	0.1
Potassium iodide (U.S.P.)	0.1
Cobalt carbonate (C.P.)	0.1

Cod liver oil was fed once every seven days, at a rate calculated to provide 58 I.U. of vitamin A and 5.6 I.U. of vitamin D per kilogram of body weight daily. The basal diet was compared with diets in which 2.5, 5.0 and 10.0 percent of Ruffex was substituted for an equal weight of starch. Fresh refrigerated lard was used to aid in preventing the diets from becoming rancid, and not more than 100 pounds of any one diet was mixed at a time.

Each group of four pigs was fed independently of the other. Within each group of four animals one received the basal ration and each of the remaining three was fed a different level of Ruffex, 2.5, 5.0 or 10.0 percent.

The animals were fed twice daily in a metal feeder fastened to the front panel of the pen and designed to prevent any feed being wasted. Sufficient water was added to the dry mixture to form a thin gruel. An attempt was made within each group of four to equalize the weight of feed eaten daily by all pigs. When one occasionally refused to eat, the remaining three were continued on full feed. Daily feed consumption records were kept and the pigs were weighed weekly.

The weight gain and feed consumption for the animals in Experiment 1 are shown in table 3. The results should be appraised for each slaughter group separately, not one group to the other, since each group of four was allotted and fed as a separate study.

Four were slaughtered when near 100 pounds in weight and the remaining group when they were near 200 pounds. Pig D49, in the "100 pound" slaughter group was injured while being weighed and was slaughtered two days prior to the slaughter of the remaining three animals. The pigs fed to the heavier slaughter weights were all slaughtered on the same day. Some of the difference in weight gain and in feed efficiency appeared to be caused by individual variation and apparently was not related to the level of fiber included in the ration. D15 was an especially thrifty pig, whereas pig D16, a litter mate, did not eat well and was difficult to keep on feed. Three of the pigs fed to "200 pounds" slaughter weight performed very much alike; pig D73, however, developed into a shorter, thicker type of pig and failed to keep up to his mates in rate of gain or in feed utilization.

Carcass characteristics were studied for each pig in this and Experiments 2 and 3. Chilled carcass weights, weights of the various cuts, and carcass measurements were recorded for all animals. None of the differences observed could be correlated with the diets fed. It was therefore concluded that the levels of Ruffex which were fed did not affect the character of the carcass.

Experiment 2

Eight purebred Hampshire barrows, four from each of two litters, were weaned at eight weeks of age and placed on experiment a few days later. All were sired by the same boar and were from closely related dams. They were farrowed and kept on pasture until weaned. As in Experiment 1, each of the groups of four pigs comprised an experimental unit. Since 10 percent of Ruffex did not have a marked effect on the

TABLE 3. WEIGHT GAIN AND FEED CONSUMPTION OF DUROC PIGS FED DIETS CONTAINING DIFFERENT LEVELS OF RUFFEX—EXPERIMENT 1
(Weights in Pounds)

Ruffex in Ration (%)	Pig Number	Initial Weight	Final Weight [1]	Average Daily Gain	Feed per lb. Gain
Group 1—Summary to "100 Pounds"					
None	D15	30	101	1.39	1.97
2.5	D16	32	94	1.22	2.17
5.0	D46	31	96	1.27	2.12
10.0	D49	29	94	1.33	2.00
Group 2—Summary to "100 Pounds"					
None	D69	22	102	1.27	1.97
2.5	D73	22	90	1.08	2.25
5.0	D61x	23	101	1.24	2.02
10.0	D52	24	100	1.21	2.08
Group 2—Summary from "100 to 200 Pounds"					
None	D69	102	202 [2]	1.64	3.18
2.5	D73	90	184 [2]	1.54	3.42
5.0	D61x	101	202 [2]	1.66	3.21
10.0	D52	100	202 [2]	1.67	3.17

[1] Weight after a 24-hour shrink for the pigs slaughtered at 100 pounds. "Full weight" for the pigs fed to a 200-pound slaughter weight.
[2] Weight after a 24-hour shrink.

growth rate of the pigs in the first experiment, higher levels were included in this experiment. Thus levels of 5, 15 and 20 percent of Ruffex were fed. Growth and feed consumption data for the eight pigs are presented in table 4.

The 15 and 20 percent levels of Ruffex brought about a decrease in both efficiency of feed utilization and rate of gain when the performance of these pigs is compared to those which received none or 5 percent. Pig H608, fed the 5 percent level of Ruffex to the lighter slaughter weight, made slightly less rapid and efficient gains than the control animal in

its group. In group 2 the performance of pig H615, fed the 5 percent level of Ruffex to the heavier slaughter weight, however, was superior to the pig fed the basal diet. This was true during both phases of the growing and fattening period.

Digestion trials were conducted to determine the apparent digestibility of the crude fiber, ether extract, protein, and nitrogen-free extract of the four different diets. Cylindrical cages constructed with some modification after those described by Bell (1948) were employed. Since only four cages were available, one group of four was placed on trial at a time. At the beginning of the digestion trials, the pigs in group 1 (table 4) had an average weight of 80 pounds; those in group 2 (table 4) 70 pounds. The fecal material was dried to a constant weight at 100 degrees Centigrade, then aliquot samples taken for analysis. Standard AOAC analytical methods were employed on the feed and fecal material. A summary of the coefficients of apparent digestibility (Trials 1 and 2) are included in table 6 and will be discussed in conjunction with the results of Experiment 3.

TABLE 4. WEIGHT GAIN AND FEED CONSUMPTION OF HAMPSHIRE PIGS FED DIETS CONTAINING DIFFERENT LEVELS OF RUFFEX—EXPERIMENT 2
(Weights in Pounds)

Ruffex in Ration (%)	Pig Number	Initial Weight	Final Weight [1]	Average Daily Gain	Feed per lb. Gain
Group 1—Summary to "100 Pounds"					
None	H607	39	104	0.97	2.78
5.0	H608	42	104	0.93	2.94
15.0	H609	36	94	0.87	3.16
20.0	H600x	36	95	0.88	3.10
Group 2—Summary to "100 Pounds"					
None	H614	35	111	1.12	2.50
5.0	H615	35	120	1.25	2.24
15.0	H616	35	108	1.07	2.61
20.0	H617	34	102	1.00	2.76
Group 2—Summary from "100 to 200 Pounds"					
None	H614	111	195 [2]	1.87	3.22
5.0	H615	120	196 [2]	2.00	2.97
15.0	H616	108	191 [2]	1.60	3.84
20.0	H617	102	188 [2]	1.65	3.71

[1] Weight after a 24-hour shrink for the pigs slaughtered near 100 pounds. "Full weight" for the pigs fed to a "200-pound" slaughter weight.
[2] Weight after a 24-hour shrink.

Experiment 3

This experiment was designed to obtain additional information on the effect produced by the same levels of Ruffex as were fed in Experiment 2. Eight purebred Hampshire barrows, sired by one boar were used in this study. The four comprising Group 1 were litter mates while in Group 2 two pigs were taken from each of two litters. They were weaned at eight weeks of age and placed on experiment immediately. All eight were slaughtered when near 100 pounds live weight. Weight gain and feed efficiency data are presented in table 5.

TABLE 5. WEIGHT GAIN AND FEED CONSUMPTION OF HAMPSHIRE PIGS FED DIETS CONTAINING DIFFERENT LEVELS OF RUFFEX—EXPERIMENT 3
(Weights in Pounds)

Ruffex in Ration (%)	Pig Number	Initial Weight	Final Weight [1]	Average Daily Gain	Feed per lb. Gain
Group 1—Summary to "100 Pounds"					
None	H633	28	97	1.13	1.86
5.0	H635	24	99	1.12	2.02
15.0	H639	25	97	1.07	2.14
20.0	H634	31	99	1.02	2.29
Group 2—Summary to "100 Pounds"					
None	H657	25	103	1.30	1.96
5.0	H675	21	102	1.35	1.93
15.0	H674	26	94	1.13	2.13
20.0	H653	26	99	1.22	2.12

Pigs slaughtered at approximately 100 pounds.
[1] Weight after a 24-hour shrink.

The results are similar to those obtained in Experiment 2. Very little difference in rate of gain is shown between the two pigs which received the 5 percent level of Ruffex and the pig in each group receiving only the basal diet. The two higher levels of roughage material again brought about a decrease in rate of gain and feed efficiency. However, pig H653 in Group 2 fed 20 percent Ruffex gained at a very satisfactory rate. The difference between this animal's rate of gain and those fed 0 or 5 percent indicates the decrease was not proportional to the additional fibrous material ingested.

A digestion study was conducted on the Group 1 animals when they weighed an average of 52 pounds (Trial 3) and on group 2 when they averaged 69 pounds (Trial 4). These data are included in table 6.

There was an apparent decrease in the digestibility of the crude protein, ether extract and nitrogen-free extract portions of the diet when the pigs were fed the higher levels of fiber. This trend is consistent in all trials. The depression in digestion of the protein and ether extract

TABLE 6. APPARENT DIGESTIBILITY OF NUTRIENTS IN DIETS CONTAINING DIFFERENT LEVELS OF RUFFEX [1]

Pig No.	Ruffex in Ration (%)	Coefficient of Apparent Digestibility (%)			
		Crude Protein	Ether Extract	Crude Fiber	N.-free Extract
		Trial 1—Experiment 2			
H614	None	95	97	Neg.	99
H615	5.0	93	94	8	99
H616	15.0	91	92	23	93
H617	20.0	89	91	25	91
		Trial 2—Experiment 2			
H607	None	95	97	Neg.	99
H608	5.0	99	95	9	98
H609	15.0	88	93	14	94
H600x	20.0	87	91	21	93
		Trial 3—Experiment 3			
H633	None	96	95	26	99
H635	5.0	93	92	1	98
H639	15.0	90	93	Neg.	92
H634	20.0	88	89	14	92
		Trial 4—Experiment 3			
H657	None	96	94	40	100
H675	5.0	93	90	3	98
H674	15.0	90	89	20	94
H653	20.0	88	87	8	91

[1] All figures rounded to the nearest whole number.

portions of the pigs' diet from the addition of fibrous material was also noted by Woodman and Evans (1947).

The coefficients for the crude fiber fraction are variable. The greatest variation occurred in the basal diet which contained less than one percent of crude fiber. Because of this low level the coefficients for crude fiber which are listed for the pigs fed no Ruffex are of doubtful significance. The remaining values indicate the Ruffex was poorly digested with a tendency for more to be digested when the higher amounts

were fed. There is no explanation for the negative coefficient obtained for pig H639 which was fed 15 percent Ruffex. These results indicate that conditions peculiar to the individual pig play a role in fiber digestion.

Forbes and Hamilton (1952) have reported results of digestion and metabolism studies in which barrows with an initial weight of 125 pounds were fed Ruffex at a level of 7.3 percent of the total diets. This level of Ruffex supplied approximately 50 percent of the cellulose in the diet. The added cellulose included in the diet from the addition of Ruffex was apparently digested to the extent of 30 percent. The authors found that there was greater digestion of the cellulose fraction than of the crude fiber portion of the diets.

In the studies reported herein there was no indication that the cellulose included in the diets acted as a growth stimulant. From 5 to 15 percent Ruffex included in purified diets fed to chicks was found to stimulate growth and apparently to increase feed efficiency when fed to chicks (Davis and Briggs, 1947).

In viewing the results of the present studies it is apparent that certain pigs were not as adversely affected by the higher levels of cellulose as were others. When the 15 or 20 percent less available starch in the higher fiber diets is considered, together with the apparent digestibility of the cellulose substituted for it, the gains of some pigs fed these high-fiber diets were quite satisfactory. An example of this is pig H653 (Experiment 3) fed a diet with 20 percent Ruffex substituted for starch and gained 1.22 pounds per day as compared to 1.30 pounds for H657, the control pig fed the basal ration. The digestion coefficient of only 8 percent obtained for the crude fiber ingested by H653 may mean in this animal that the fibrous material performed some additional role other than supplying energy.

The individual variation in the pig's ability to make use of fiber demonstrated that the effect on growth and feed efficiency from feeding the same level cannot be accurately predicted even though the chemical and physical nature of the fiber is the same.

Summary

Twenty-four individually fed pigs were employed in three separate studies to observe the effect of feeding diets in which from 5 to as high as 20 percent of the corn starch in a purified basal ration was replaced by a cellulose product (Ruffex).

Although considerable individual variation was encountered, growth rate and feed utilization appeared to be adversely affected by the higher levels of Ruffex ingested.

Results of digestion trials showed the crude fiber of the diets to be poorly digested at all levels and its inclusion depressed the apparent digestibility of the protein, nitrogen-free extract, and ether extract portions of the diet.

Carcass characteristics could not be correlated with the level of fibrous material fed.

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A SUMMARY OF FOUR YEARS WORK IN RAM PROGENY AND PERFORMANCE TESTING

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FEW sheep breeders have the necessary assistance, time and facilities to conduct a progeny and performance testing program. Even if they were able to conduct such a program within their flocks the value would be limited, because most breeders select stud rams outside their own flock. With these facts in mind personnel of the Texas Agricultural Experiment Station at the Ranch Experiment Station located in the Edwards Plauteau entered into a cooperative agreement with purebred sheep breeders of the state to carry on a program of sire testing. The fourth, in what is planned to be a series of tests, culminated with the field day at the Station on May 17, 1952. The theoretical considerations concerning progeny testing have been discussed by a number of authors including Lush (1935) and Dickerson and Hazel (1944). In general the conculsions are that, aside from certain practical limitations, it is an effective aid to selection. In actual progeny testing work with sheep Williams (1948) and McLean (1952) failed to demonstrate any significant sire differences for birth weight and growth rate of lambs while nursing. However, the latter did find significant differences between sires for dressing percentages and various body measurements. The objects of this testing program are as follows:

(a) Locate superior stud rams that are most prepotent for the various characters,
(b) Obtain production figures on young rams from different parts of the state under comparable conditions in order that selection of future stud rams may be more effective,
(c) Determine the most practical and efficient methods of stud flock improvement through progeny testing of rams for breeders.

In addition to providing this service for breeders, an opportunity is presented for Experiment Station personnel to study the importance, inheritance and genetic and physiological relationships of the various factors studied. Regardless of the effectiveness of efforts to locate

[1] The authors gratefully acknowledge the contribution of the following people: The late W. H. Dameron under whose leadership this work was originally started; Mr. Stanley P. Davis for conducting the detailed work on wool technology; Mr. O. L. Carpenter as a co-worker; Dr. Robert R. Shrode for suggestions in preparation of the manuscript; and cooperating sheep breeders.

superior sires this work to date has been of value through (1) the encouragement given breeders to use accurate and detailed records in selection as a replacement for the highly fallible method of show ring evaluation, (2) pointing out to the breeders the characteristics that contribute greatest to value in the animal, and (3) encouraging breeders to consider overall merit in selection rather than to select for one or more superficial characteristics singly or separately.

Materials and Methods

Purebred sheep breeders over the state are invited to send groups of lambs by the same sire and born the previous lambing season to the station for testing. No restrictions are placed on the manner in which these lambs are selected. This results generally in the testing of a selected group of lambs. This is justified by the reasoning that it is done by all cooperators, and since this test is a performance as well as a progeny test, the effort is merited only on the better individuals. In the two first years of the test the number of animals per sire group was set at a minimum of six and a maximum of ten. In the last two years a sire test group consisted of only four animals. The first year's test began on July 21 and continued for 308 days. The second test began August 20 and continued 277 days. In later years the test began the first week in September and continued 224 days. Investigation of the data for the early years indicated that the length of test and number of animals could be reduced and that the additional sire groups this would permit testing should more than offset the loss in reliability of the data. Data on rate of gain are based on a total for this period of time, but the figures concerning wool production (grease and clean wool and staple length) have been converted to 365 days. Breeders pay for the feed consumed and the Experiment Station provides the necessary facilities and personnel to conduct the work.

Soon after delivery at the station all lambs are drenched for stomach worms, sheared and dipped or sprayed. As soon as possible after this work is completed, the lambs are officially started on feed. The rams are fed according to appetite on a practical growing ration consisting of oats and alfalfa hay. In the two early years a little cottonseed meal was used.

In the first two years all animals were fed together in large pens. In the later two years three different feeding arrangements have been used. Some of the rams were fed in large groups as before. A second group was fed in 30 small pens which were built to accommodate sire groups

of four rams in each pen. The purpose of these was to permit keeping of feed consumption records by sire groups. A third method of feeding consisted of feeding oats alone on the range. Range conditions, over these two years, were poor and these latter groups have not performed well.

The rams are weighed at 28-day intervals. Shortly prior to the end of the feeding period the rams are scored for face covering and belly covering. Following the last weigh day the rams are sheared and scored for body conformation. The scoring is done by a committee of Experiment Station personnel and Sheep Breeders. The scoring system used is as follows:

Body conformation—Excellent 1, Good 2, Medium 3, Poor 4.
Belly covering—Dense covering 1, Medium covering 2, Poorly covered 3, Bare 4.
Face covering—Open 1, Medium 2, Covered 3, Wool blind 4.

Scouring reports, spinning counts and staple length determinations were made at the wool scouring plant at Bluebonnet Farm (T.A.E.S. Substation 23) McGregor, Texas. Skin fold values were taken immediately after shearing in a manner described in detail by Jones *et al.* (1946). Briefly the values represent a total score for each animal based on the number, size and location of individual folds. The higher the score, the greater is the number of skin folds.

As is shown in table 1 a total of 576 rams, representing the get of 98 different sires, have completed the test. A total of 34 different breeders have cooperated in this work and many of these had animals in the test each of the four years.

Results

The volume and diversity of the data collected in this project precludes a brief or simple presentation and analysis. The average figures arranged by breeds and years are presented in tables 2 and 3. From this can be obtained a breed comparison if such is desired. Perhaps more important an opportunity exists to study the data by years in search of some indication of progress. However, such should not really be expected since on the average less than one generation of sheep breeding has elapsed since the start of this work. There has been an important increase in the daily gain and clean wool production. It is the hope and belief of those connected with the work that some progress has been made, but the increase noted here may perhaps be attributed more to an improvement in methods of conducting the test and to an im-

TABLE 1. NUMBER AND BREED OF RAMS BY YEARS

Year	Total Number Rams	Total Number Breeders	Total Number Sires	Number of Rams by Breeds						
				Rambouillet	Corriedales	Columbia	Merino	Debouillet	Suffolk	Crossbred
1948–49	88	13	15	88	..	..	..	..	..	..
1949–50	126	18	23	86	16	..	18	6	..	..
1950–51	152	19	32	109	14	12	8	..	..	9
1951–52	210	24	43	158	15	14	12	..	7	4
Total	576	34	98	441	45	26	38	6	7	13

The total for the number of breeders and sires is not the sum of the two colums, but represents the number of different individuals. The breeders tend to be the same year after year, and some breeders have tested the same sire in subsequent years.

TABLE 2. COMPARATIVE DATA BY BREEDS AND YEARS [1]

Year	Breed	Initial Weight	Final Weight	Daily Gain	Grease Wool	Clean Wool	Staple Length in.	Fineness [4]	Skin Folds	Body Conformation	Belly Wool	Face Covering
1948–49	Rambouillet	74.9	187.6	.37	13.8	6.6	3.37	....	33.8	2.2	...	2.7
1949–50	Rambouillet	85.0	211.9	.45	16.7	7.9	3.57	....	38.9	...	2.4	2.8
	Corriedale	84.1	185.2	.39	15.5	8.4	4.74	....	11.3	...	2.0	1.5
	Merino [2]	58.9	149.5	.32	16.7	7.0	3.49	....	58.4	...	1.8	1.9
	Debouillet	78.2	180.3	.37	18.0	7.0	4.39	....	11.2	...	2.8	1.4
1950–51	Rambouillet	83.8	195.1	.50	18.0	8.1	3.34	21.1(64s)	44.8	2.4	2.6	2.7
	Corriedale	71.0	178.6	.48	17.9	9.8	4.65	29.0(56s)	19.2	2.0	2.2	1.3
	Columbia	78.9	194.7	.52	17.1	9.5	4.65	29.0(56s)	11.3	1.8	3.5	1.0
	Merino [2]	65.9	161.0	.43	19.2	8.4	3.64	22.4(64s)	48.4	2.9	1.9	1.6
	X-Breed [3]	64.4	156.5	.40	13.4	6.2	3.23	19.5(70s)	24.8	2.6	3.0	2.1
1951–52	Rambouillet	85.3	187.1	.46	17.7	8.2	3.47	19.7(70s)	25.1	2.3	2.7	3.3
	Corriedale	66.3	162.7	.43	18.3	9.5	4.39	27.7(56s)	11.9	2.8	2.8	2.1
	Columbia	65.3	167.4	.46	16.8	9.2	4.87	27.3(56s)	5.8	2.3	2.8	1.1
	Merino [2]	60.2	153.2	.42	18.1	7.1	3.61	20.0(70s)	27.8	2.3	2.3	1.7
	Suffolk	130.1	224.6	.42	10.0	5.2	3.09	31.7(48s)	5.4	2.0	3.9	1.0
	X-Breed [3]	69.0	142.7	.33	13.1	6.7	3.70	19.5(70s)	10.2	2.5	2.7	1.2
Aver.	Rambouillet	82.8	199.7	.45	16.7	7.8	3.44	20.4(70s)	34.4	2.3	2.6	2.9
	Corriedale	74.1	173.6	.43	17.1	9.2	4.59	28.4(56s)	13.9	2.4	2.3	1.6
	Columbia	71.6	179.9	.48	16.9	9.3	4.77	28.1(56s)	8.4	2.1	3.1	1.0
	Merino [2]	60.8	153.1	.38	17.7	7.3	3.56	21.2(70s)	46.6	2.5	2.2	1.8
	Debouillet	78.2	180.3	.37	18.0	7.0	4.39	....	11.2	...	2.8	1.4
	Suffolk	130.1	224.6	.42	10.1	5.2	3.09	31.7(48s)	5.4	2.0	3.9	1.0
	X-Breed [3]	65.8	151.9	.38	13.3	6.3	3.39	19.5(70s)	19.9	2.6	2.9	1.8

[1] Excluding pasture fed sheep.

[2] Included in this group are Delaine Merinos and one or more sire groups each year of strong wool Merinos from New Zealand. These latter sheep have long staple wool which is coarser than typical Merino wool. These facts should be kept in mind when considering the average figures given here.

[3] The animals listed here as cross-breds are not first cross animals and should not be considered in any way as a test of hybrid vigor. These animals might more correctly be known as experimental animals. They represent an inbred strain based on a Rambouillet X Romney back-cross.

[4] Diameter of fibers in microns as obtained by the comparator method. Subsequent references to fineness will be made in like manner.

proved ability on the part of the breeders to select the more productive individuals. It will be noted that there is a conspicuous lack of progress in respect to body conformation and face covering as indicated by the scores, especially in the case of the latter. If this is true it is regrettable because both of these are important characters in a sheep breeding program. Since both these characters are dependent upon human evaluation in scoring, it has been suggested that perhaps a comparison between years is not valid. Judges would tend to adopt a central tendency within the year and would not be consistent from year to year. If the scores are accurate as given and indicate a lack of progress or backward tendency it can likely be attributed to the fact that in the test the spotlight has been placed on the productive characters resulting in a sacrifice in certain others.

TABLE 3. COMPARATIVE DATA BY YEARS—RAMBOUILLETS ONLY

Year	Daily Gain	Clean Wool	Staple	Skinfolds	Body Conf.	Face Cov.
	lb.	lb.	in.			
1948–49	.37	6.6	3.37	33.8	2.2	2.7
1949–50	.45	7.9	3.57	38.9	...	2.8
1950–51	.50	8.1	3.34	44.8	2.4	2.7
1951–52	.46	8.2	3.47	25.1	2.3	3.3

One of the first objects of this work was to locate superior stud rams. Evidence that efforts on this point have been successful can be obtained from a study of figure 1. Nine sire group averages of Rambouillets selected from each year's test are presented graphically with respect to the average of that breed for that year, to illustrate that efforts have been successful in identifying rams that are above or below average with respect to the three important characteristics; daily gain, clean wool production and staple length. For those proponents of the method of corrective mating certain other sire averages are presented to indicate that many sires prove exceptionally weak or strong with respect to certain of these characteristics. The amount of data is not sufficient to permit doing this for the other breeds. As is shown in table 4 important and highly significant sire differences have been found for all of the characteristics studied. Significant breed differences were found for all characteristics except daily gain.

In table 5 are presented the gross correlation coefficients between the various characteristics studied. Many of these are so small as to be unimportant and only a few merit special consideration. Some

PROGENY TEST – RAMBOUILLETS

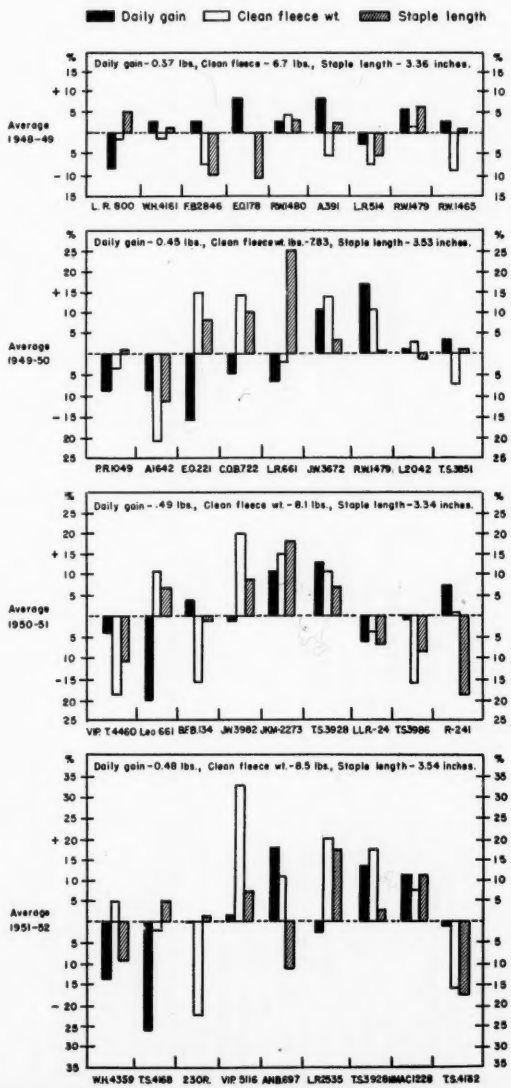
Daily gain
Clean fleece wt.
Staple length
Daily gain – 0.37 lbs., Clean fleece – 6.7 lbs., Staple length – 3.36 inches.
Average 1948–49
L.R. 800 WH.4161 FB2846 EQ178 RN1480 A391 LR514 RN1479 RN1465
Daily gain – 0.45 lbs., Clean fleece wt. lbs. – 783, Staple length – 3.53 inches.
Average 1949–50
PR.1049 AI642 EQ221 COB722 LR661 JW3672 RN1479 L2042 TS3851
Daily gain – .49 lbs., Clean fleece wt. – 8.1 lbs., Staple length – 3.34 inches.
Average 1950–51
VIP T4460 Lao 661 BFB.134 JW3982 JKM-2273 TS3928 LLR-24 TS3986 R-241
Daily gain – 0.48 lbs., Clean fleece wt. – 8.5 lbs., Staple length – 3.54 inches.
Average 1951–52
WH.4359 TS.468 230R VIP 5116 ANB697 LR2535 TS3928 MAC1228 TS.4182

Figure 1. Performance of certain sire groups as compared to the average of all Rambouillets for same year.

TABLE 4. MEAN SQUARES FOR BREEDS AND SIRES

Source	Df	Daily Gain	Clean Wool	Staple Length	Face Cov.	Skin Folds	Body Conf.	Df	Belly Cov.	Df
Breeds within subgroups [1]	10	.040	13.61**	6.77**	17.66**	4354.**	1.33**	(8)	2.11**	(11)
Sires within breeds and subgroups	105	.076**	3.86**	.47**	1.13**	801.**	.36**	(86)	.86**	(70)
Within sires	426	.021	.70	.11	.09	410.**	.11	(328)	.07	(353)

[1] Subgroups consist of years and feeding arrangement within years. Excluded from this table are all crossbreds and purebreds in which two or more sires were not present in a breed and subgroup.

** Probability of 0.01.

TABLE 5. CORRELATION COEFFICIENTS FOR VARIOUS CHARACTERISTICS STUDIED

Corriedales and Columbias Combined

Rambouillets Only	Initial Weight	Final Weight	Average Daily Gain	Feed per 100 lbs. Gain	Grease Wool Weight	Clean Wool Weight	Staple Length	Fiber Diameter	Body Conformation	Belly Covering	Skin Fold Values
Initial weight		.79**	.43**	...	.50**	.46**	.00	.34**	—.20	.18	.22
Final weight	.69**		.88**	...	.52**	.44**	—.07	.28*	—.39**	.25*	.34**
Average daily gain	.00	.72**		...	.35**	.29*	—.03	.21	—.39**	.26*	.37**
Feed per 100 lbs. gain	.85**	.42**	—.63**		...	...	...	...	...	...	...
Grease wool weight	.49**	.64**	.34**	.29*		.82**	.11	.30*	—.02	—.19	.33**
Clean wool weight	.36**	.53**	.31**	.30*	.81**		.30*	.44**	—.18	—.14	.23
Staple length	.02	.03	.01	—.14	.27**	.40**		.03	.12	—.05	—.51**
Fiber diameter	.05	.22**	.24*	—.12	08	.00	—.26*		...	.02	.25*
Body conformation	—.36**	—.29**	—.26**	—.11	—.16**	—.15**	—.03	—.02		—.03	.05
Belly covering	—.13**	—.07	.00	—.17	—.39**	—.39**	.13**	—.13*	—.03		.18
Skin fold values	—.07	.12*	.19**	—.17	.44**	.24**	—.22**	.23**	.19**	—.57	
Face covering	—.12**	—.10*	—.07	.11	.27**	.31**	.06	.08	.15*	—.13*	.19**

* Probability of 0.05.
** Probability of 0.01.

of these are discussed briefly. Care should be used in interpreting these correlation values. Many traits were scored so that the lowest value is the most desirable. Therefore, when these traits are associated with traits in which the highest value is the most desirable, a negative correlation means a positive relationship in terms of merit.

Initial Weight

Initial weight has been found to have an important influence on the performance of the animal during the test. There is a highly significant correlation between initial weight and clean and grease wool production, and between initial weight and body conformation in all breeds, and in the case of Corriedales and Columbias it is correlated with daily gain. This difference between the breeds in respect to the correlation between weight and gain is likely due to the fact that Corriedales and Columbias were all Spring lambs whereas the Rambouillet have been Fall, Winter and Spring lambs. Maturity and fattening has tended to slow down the gain for the larger Rambouillets. The association between initial weight and body conformation is obvious in that the larger animals carry more flesh at the end of the test resulting in a higher type score. By means of a regression equation wool production and body conformation have been adjusted to a constant initial weight in the heritability analyses that follow.

Daily Gain

Average daily gain is significantly correlated with wool production and body conformation. The association between wool production and rate of gain can be explained first in that wool production is a part of the total gain, and second that the higher productivity would be expressed both in gain and wool production. The relationship between rate of gain and body conformation is obvious in that those making the rapid gain would be larger and carry more flesh at the end of test. It is inconceivable that this would not affect type scores.

Feed Efficiency

By the method of multiple correlation, more than 90 percent of the variation in feed efficiency can be accounted for by a knowledge of initial weight, rate of gain and other related variables. Little or no value has been realized from the data collected on this point. This

has also proved a confusing point to cooperators in that many do not realize the causes of the tremendous differences in feed efficiency.

Staple Length

Staple length is significantly correlated with wool production and skin folds (negative). In the case of Rambouillets there is a significant negative correlation with fiber diameter. This appears to be in contrast to the general tendency, especially between breeds and types of sheep. No explanation is offered here, but if this is a true relationship for the Rambouillet breed as a whole and not simply a peculiarity of the group under study, this reationship should facilitate the development of a long staple fine wool sheep.

Fiber Diameter

There is a small but significant correlation of fiber diameter with size, rate of gain, and skin folds. In the case of Corriedales and Columbias the coarse wooled sheep produced more wool .

Belly Covering

Belly covering is highly correlated with wool production. It is the opinion of many connected with this work that when actual records of wool production are used as a basis for selection, belly covering may be ignored. When selection is based on visual evaluation, belly covering would merit consideration. Selection directly for belly covering, except as it is expressed in increased wool production would in fact be selecting for the inferior type of wool as produced on the belly.

Skin Folds

The relationships involving skin folds have been discussed elsewhere (Shelton *et al.* 1953) for the Rambouillet. For the other breeds skin folds are of less importance, but the relationships seem to be much the same.

Face Covering

Open faced lambs tend to gain faster (non-significant) and the woolly faced lambs tend to produce more wool. None of the relationships are sufficiently high to have any great predictive value. The handicap of the wool on the face had no effect during the study since the rams' faces were trimmed to prevent wool blindness.

Heritability Estimates

An early step in the application of the results of this work was to obtain estimates of heritability of the important traits of sheep under these conditions. In practice the data have proved something less than ideal for this work. Heritability estimates based on work of this type have special value in that they might be applied to the sheep population in general over this area in contrast to one isolated flock. Few breeders depend on a selection program completely within their own flocks.

The data lend themselves only to the method of half-sib correlation. When an analysis is made using data on all the animals the magnitude

TABLE 6. ANALYSIS OF VARIANCE FOR CLEAN WOOL PRODUCTION[1]

Source	Df	SS	MS
Total	212	387.3	
Years	3	78.4	
Ranches W/in years	13	124.3	
Sires W/in ranches and years	28	48.2	1.72**
Within sires	168	136.4	.81

$r_I = .192$ $\qquad h = \frac{.192}{R_{xy}} = .61$

** Probability of 0.01.

1 Table 6 contains only those sire groups where there was more than one sire group per year-ranch sub-group. If a sire was used in two years or in two flocks the same year, he was considered as a different sire each time and place used.

of the heritability estimates are tremendous, and in many cases it is well above 100 percent. There are a number of factors that are likely contributing to this such as:

1. Maternal genetic influence confounded with sire,
2. Pre-test environmental differences,
3. Selection of uniform samples.

A number of cooperators each year test more than one sire group. This permits a break down on a within-ranch basis which tends to remove a part of the influence enumerated above. An example of this type of analysis is given in table 6 for clean wool production. Heritability (h) was determined by dividing the Phenotypic intraclass correlation (r_I) by the average coefficient of relationship (R_{xy}=.3135). The heritability estimates obtained by this method are given in table 7. These heritability estimates in general tend to be higher than those

previously reported in the literature. (Hazel and Terrill, 1945, 1946; Terrill and Hazel, 1943, 1946; Jones *et al.* 1946).

Most readers will be aware that heritability estimates obtained by half-sib correlation tend to contain components of variation other than that due to regression of phenotype on genotype. This in general results in estimates of this type being higher than might other wise be expected. Even assuming they are higher does not invalidate use of these estimates because heritability estimates are of value only in that they are comparable with those for other characteristics within the population under study. Very encouraging with respect to this work are the high heritability estimates obtained for the production characters (rate of gain and wool production) indicating that if these estimates are valid, continued effort in this type of work should prove of value in improving the performance of the sheep population in general.

TABLE 7. HERITABILITY ESTIMATES OBTAINED BY HALF-SIB CORRELATION

Face covering	.48	Yield	.43
Belly covering	.36	Daily gain	.58
Body conformation	.20	Skin folds	.20
Staple length	.67	Clean wool	.61
Fiber diameter	.57	Grease wool	.66

Summary

A summary of four years work in progeny and performance testing of rams is reported. A total of 576 rams consisting mostly of Rambouillets with a smaller number of Corriedales, Columbias, Merinos and Suffolks have been full fed on a ration of oats and alfalfa and studied in detail. Data are presented to indicate that important and highly heritable differences exist between the performance of offspring of different sires. Other data are presented to show the phenotypic correlation existing between the various characteristics on which data were collected as possible aids in selection.

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A METER FOR STUDYING QUANTITATIVE WOOL DIFFERENCES AMONG SHEEP [1]

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BASICALLY, the prediction of clean wool production depends on three physical measurements: the amount of surface on which the wool is grown, the length of the wool, and the amount of wool produced on a unit of area. Roughly then, this represents a solid within which varying densities (or weights of wool) are produced. Body weight has been found to be an adequate expression of body surface for wool production, and a measured lock from the hip has given excellent results as an indicator of average length. Both of these measurements have shown high correlations with clean fleece weight (Ali *et al.*, 1953). The measurement of density has proved considerably more difficult.

Results and Discussion

Numerous methods of measuring this variable have been introduced: Hardy (1932), Wildman (1936), Burns (1937) and Wolf *et al.* (1943). The use of these methods, however, necessitates either tedious counting of fibers or controlled laboratory conditions for the measurement of samples taken.

It was therefore considered necessary to develop an accurate, rapid method of showing quantitative differences in body covering, so that these could be obtained in the field, without recourse to the laboratory.

After considerable experimentation, a measuring device known as the "Neale Density Meter" (figure 1) has been developed to show these differences.

The device works on the principle of two forks maintained at a constant pressure by a spring, and the amount of wool held between them is measured by the space that it occupies between the forks. The distance between the tines when open is one inch, and when pressure is applied, the space between the points (wool volume) is read from a dial scale calibrated in ten thousandths of an inch.

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Repeatability

The repeatability (accuracy of measurement) of the instrument was determined by a preliminary analysis in which three or more measurements were taken on each of eleven sheep. All measurements were made on the hip.

A highly significant difference was found in variation between sheep when tested by within sheep mean square, indicating an accuracy of repeatability, although readings were taken consecutively and may not have been completely independent.

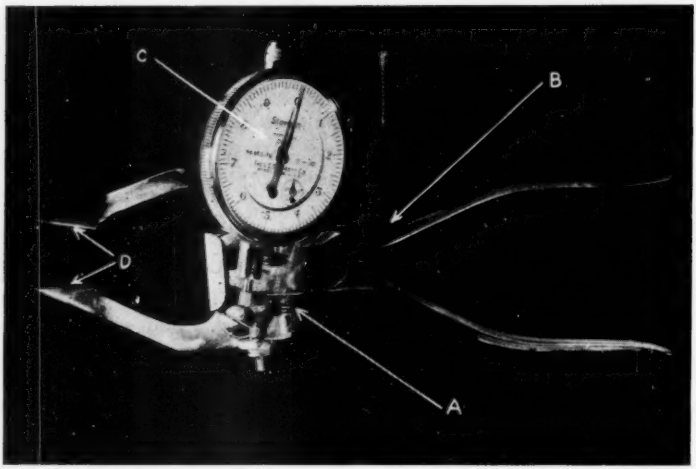

Figure 1. The Neale density meter. a. constant pressure spring. b. stop to control size of fork opening. c. dial for recording width between points (d) when pressure is applied. d. forks which are placed against skin when measuring (relaxed opening 1").

This objection was overcome by the introduction of a time lapse and by use of two different operators. Two readings were taken on a group of Rambouillet and Corriedale yearling ewes on different days by each operator. This insured independence between readings, resulting in unbiased estimates of the mean and variance. Although experimentation with the device had shown that a slight change in the position of the animal or a change of a few inches in the place measured would give different readings, satisfactory results were obtained.

TABLE 1. ANALYSIS OF VARIANCE DENSITY READINGS ON 27 YEARLING EWES

Source of Variation	D/F	Operator 1 [a] MS	Operator 2 [a] MS	Operator 1 and 2 [b] MS
Between measurements	1	289	766	3220**
Between sheep	26	974**	1576**	989**
Within sheep	26	342	191	389

[a] Two measurements made on each ewe with a time lapse of two days between measurements.
[b] A single measurement made on each ewe by each operator.
** Significant at the .01 probability level.

Differences between sheep (table 1) were highly significant, while those between measurements on different days by the same operator did not approach significance. Considerably more variation was found between readings by different operators than between readings by the same operator. Components of variance percentages were computed to analyze both differences (table 2).

The greater amount of variance is attributable in all cases to differences between sheep and the amount attributable to differences between readings by the same operator is inconsequential. The data also indicate that when all readings are made by a single operator, the variable of operator error may be discounted in the interpretation of density data obtained with this device.

Percentage differences between operators, while not so small as between measurements by the same operator, still show that by far the greater portion of variance is attributable to differences between sheep rather than to differences in technique or inherent mechanical error.

Sampling

The investigations which led to the development of the machine showed that the density of an individual sheep varied on different

TABLE 2. PERCENTAGE COMPONENTS OF VARIANCE-DENSITY READINGS

Source of Variation	Operator I		Operator II		Between Operators	
	s^2	%	s^2	%	s^2	%
Between readings	0.00	0	23.00	3.2	108.88	26.6
Between sheep	316.00	100	692.45	96.8	300.00	63.4

portions of the body. If the machine were to be used in the prediction of clean wool, some method of sampling had to be devised.

Forty-eight sheep were used for this portion of the experiment and were measured on the hip, side, and shoulder. Results were correlated with the average of the three measurements, under a modification of Wolf's system (Wolf *et al.*, 1943), with whose figures the results were in basic agreement.

Inasmuch as all correlation coefficients were highly significant (table 3), it seems that as long as any one area is chosen and that area measured in all cases, there is little to be gained by using any specific area. The choice seems to be a matter of individual preference. It is to be emphasized, however, that the same spot should be chosen on each sheep.

TABLE 3. CORRELATION COEFFICIENTS, SINGLE MEASUREMENT TO AVERAGE MEASUREMENT

Animals	Mean Density	Hip r	Side r	Shoulder r
26 Fine wool rams	320	.91**	.85**	.89**
22 Rambouillet yearling ewes	307	.88**	.90**	.85**

** Correlation significant at the .01 probability level.

Because of the ease of anatomically locating a specific point on the hip and as a result of length studies (Neale, unpublished), the hip area receives preference at the New Mexico Agricultural Experiment Station.

Relation of Density to Clean Wool

One hundred and twenty range medium wool ewes were measured on the hip for density, weighed, and a hip lock sample measured unstretched for length. The fleeces from these ewes were scoured and clean wool per fleece adjusted to standard conditions, in accordance with A.S.T.M. procedure.

The results were tabulated and analyzed. The simple correlation coefficient was computed between density and clean fleece weight as .30 (significant at the .01 probability level). In addition, the partial regression coefficient (density to clean fleece weight with body weight and wool length constant) was ascertained. The partial regression of .00735144 was tested by its standard error of .00206698, giving a t value of 3.5, again significant at the .01 probability level.

The above data indicate that a relationship exists between the density reading and clean wool production and that this relationship can be used to improve clean wool prediction.

Summary

An appraisal of wool density is necessary to improve predictions of shearing ability for individual sheep both for selection of individuals and estimation of shrinkage. For this purpose, a density meter has been developed to show differences in amount of covering between individual animals.

Working with a group of sheep at the New Mexico Agricultural Experiment Station, two operators made independent observations with the new device. Individual sheep were measured on two separate occasions by both operators to test the repeatability of the instrument.

Each operator measured highly significant differences between sheep, with negligible differences between observations, thus indicating high repeatability for the instrument. Differences were noted between operator readings, but percentage computations of components of variance showed these differences to be smaller than between sheep variance.

Sampling of individual areas showed little to choose among hip, side, or shoulder measurements. Because of the ease of locating a specific area on the hip, this spot for measurement is preferred.

Simple correlation and partial regression coefficients showed that there was a highly significant relationship between density machine readings and clean wool production.

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SUPPLEMENTATION OF FARM ROUGHAGES FOR PREGNANT EWES IN DRY LOT[1]

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EXPERIMENTAL work at Purdue University (Harper, 1940; Shrewsbury *et al.*, 1942, 1943, 1946) has shown that high quality legumes such as alfalfa hay and dehydrated oat or rye grass are superior to non-leguminous roughages for meeting the nutritional requirements of breeding ewes during gestation and lactation. When ewes were fed oat straw, corn silage, or corn cobs as the principal roughage, they produced less milk and weaker lambs which grew at a slower rate during the first six to eight weeks of age.

The nature of the nutritional deficiences in poor quality roughages is not clearly understood. It is important, therefore, to know more of such limitations and their effects upon ruminant nutrition. It is likewise important to determine what factors are contributed by alfalfa and other high quality legumes but which are inadequate in poor quality roughages and grains.

At present, little is known in regard to the specific nutrients that are required for the proper nutrition of the unborn lamb and likewise the nutritive requirements for optimum lactation in ewes. In these experiments it was desired to determine whether low grade roughages such as ground corn cobs might be supplemented to produce as good wintering performance with pregnant ewes in dry lot as a standard ration of fair to good quality hay. Also, it was desired to study the effect of supplementing corn and grass silages for pregnant ewes.

Experimental

A series of three experiments was conducted with 566 crossbred Hampshire-Rambouillet ewes—176 in the first, 240 in the second, and 150 in the third experiment.

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 729, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2] A part of the data in this paper was submitted by the senior author in a thesis for the degree of Master of Science.

All ewes were pasture bred to purebred Hampshire rams. After breeding, the ewes were divided into equal groups and received gestation and lactation rations in dry lot until pasture was available in the spring. The ewes were individually identified and weighed at 28-day intervals. The lambs were individually identified at birth and weighed at 14-day intervals. All lambs were docked and males castrated at approximately two weeks of age. All rations were balanced and altered to meet the nutritive requirements during gestation and lactation as outlined by Pearson *et al.* (1949).

In Trial III, ewes in corn cob lots (I and II) received 0.5 pound of shelled corn per ewe per day in addition to cobs and supplement. Mixed tocopherols (70 mg. per ewe daily) were added to supplements used in Trial III 50 days before parturition.

Data were analyzed by the method of analysis of variance as outlined by Snedecor (1946).

Trial I—1950–51

Lot I. (Basal ration) Ground corn cobs fed free choice and a supplemental mixture containing expeller soybean meal, molasses feed, steamed bone meal, iodized salt and a vitamin A and D concentrate. A free choice mineral mixture composed of two parts steamed bone meal to one part trace mineralized salt plus plain salt free choice was available at all times.

Lot II. Basal ration plus 100 mcg. vitamin B_{12} per ewe daily.

Lot III. Basal ration plus thiamin, riboflavin, niacin, calcium pantothenate, pyridoxine, choline, folic acid, biotin, alpha tocopherol, menadione and vitamin B_{12}.

Lot IV. Basal ration plus 1.0 lb. dehydrated alfalfa meal per ewe daily.

The corn cobs fed were ground through a half inch screen. The four lots of ewes were bedded with crushed cobs.

A creep ration composed of equal parts whole oats and shelled corn was available to the lambs. Any lambs weighing ninety pounds or more at the end of any weigh period were removed from the experiment and marketed.

TABLE 1. EWE WINTERING RATION STUDY

Trial I. 1950–1951

Item	Lot I Cob Control	Lot II Vitamin B_{12}	Lot III B-Complex	Lot IV Alfalfa Meal
	WINTERING RATION			
	Daily, lb.	Daily, lb.	Daily, lb.	Daily, lb.
Ground corn cobs	2.56	2.57	2.61	2.44
Minerals [1]	free choice	free choice	free choice	free choice
Supplemental mixture				
Soybean oil meal [2]	.50	.50	.50	.50
Molasses feed [3]	1.00	1.00	1.00	1.00
Steamed bone meal	.04	.04	.04	.04
Conc. cod liver oil [4]	.01	.01	.01	.01
Iodized salt	.03	.03	.03	.03
Vitamin B_{12} suppl.[5]		3.63 (gms)		
Complex vitamin mixture [6]			14.14 (gms)	
Alfalfa meal				1.00
	Ewe Performance			
No. of ewes at start	44	44	44	44
No. of ewes at end	35	39	36	38
Initial weight, lb.	182	181	182	182
Pre-parturient weight, lb.	228	226	230	231
Parturition weight loss, lb.	26	25	32	16
Wool clip, lb.	11.5	10.9	11.5	13.5
No. of ewes that lambed	36	36	42	37
No. of lambs dropped	54	62	61	59
Percent lamb crop (dropped)	150	172	145	159
Percent lamb crop weaned	114	117	105	103
Av. birth weight, lb.	10.0	10.0	10.6	10.4
Av. daily gain to weaning, lb.	0.60	0.61	0.61	0.61

[1] Minerals consisted of 2 parts steamed bone meal to 1 part trace mineralized salt plus loose salt free choice.

[2] Expeller soybean meal.

[3] A 45% molasses feed dried on oat hulls and other constituents to facilitate mixing.

[4] 2250 I.U. vitamin A and 400 I.U. vitamin D per gram.

[5] 12.5 mg. of vitamin B_{12} per pound of supplement. (100 mcg. per ewe daily).

[6] Vitamin complex mixture gave each ewe the following vitamins in the listed amounts, per day:

Thiamin HCL	2 mg.	Alpha Tocopherol	70 mg.	Pyridoxine HCL	3 mg.
Riboflavin	5 mg.	Menadione	2 mg.	Choline Chloride	2.5 gm.
Niacin	30 mg.	Vitamin B_{12}	100 mcg.	Folic Acid	6.5 mg.
Calcium Pantothenate	20 mg.			Biotin	10 mcg.

[7] Dehydrated alfalfa meal of 17% protein content.

Trial II—1951–52

Lot I. Basal supplement (see table 2) plus ground corn cobs fed free choice.

Lot II. Basal supplement plus vitamin B_{12} and ground corn cobs fed free choice.

TABLE 2. EWE WINTERING RATION STUDY

Trial II. 1951–1952

Item	Lot I Cob Control	Lot II Control plus B_{12}	Lot III Corn Silage	Lot IV Grass Silage
	WINTERING RATION			
	Daily, lb.	Daily, lb.	Daily, lb.	Daily, lb.
Ground corn cobs	1.93	2.00	....	....
Corn silage	....	....	7–10	....
Grass silage	....	....	....	8.26
Minerals [1]	free choice	free choice	free choice	free choice
Supplemental mixture				
Soybean oil meal [2]	.60	.60	.60	.60
Corn sugar [3]	.10	.10	.10	.10
Steamed bone meal	.05	.05	.05	.05
Iodized salt	.03	.03	.03	.03
Vit. A and D conc.[4]	.014	.014	.014	.014
Vit. B_{12} suppl.[5]	....	.008	....	....
	Ewe Performance			
No. of ewes at start	60	60	60	60
No. of ewes at end	50	49	59	54
Initial weight, lb.	134	134	135	134
Pre-parturient weight, lb.	143	144	159	158
Parturient weight loss, lb.	13	12	8	6
Wool clip, lb.	7.8	8.2	9.1	9.1
No. of ewes that lambed	53	52	50	54
No. of lambs dropped	76	69	72	70
Percent lamb crop (dropped)	143	133	144	130
Percent lamb crop weaned	42 [6]	38 [6]	54 [6]	54 [6]
Av. birth weight, lb.	9.3	10.0	10.6	9.8
Av. daily gain to weaning, lb.	.41	.43	.43	.45

[1] Minerals consisted of 2 parts steamed bone meal and 1 part cobalt salt. (One ounce cobalt sulfate per 100 pounds plain salt).
[2] Solvent extracted soybean oil meal.
[3] Cerelose.
[4] 2250 I.U. of vitamin A and 400 I.U. of vitamin D per gram.
[5] 12.5 mg. per pound of supplement. (100 mcg. per ewe daily).
[6] Percent lamb crop weaned was greatly reduced by a severe manifestation of "stiff lamb disease".

Lot III. Basal supplement plus corn silage fed free choice.

Lot IV. Basal supplement plus grass silage fed free choice.

All lots received a free choice mineral mixture in addition to the above rations. This mineral mixture contained two parts steamed bone meal and one part plain salt. The salt was fortified with one ounce of cobalt sulfate per 100 pounds of salt.

TABLE 3. EWE WINTERING RATION STUDY

Trial III, 1952–1953

Item	Lot I Cobs Sugar Suppl.	Lot II Cobs Molasses Suppl.	Lot III Corn Silage Only	Lot IV Corn Silage Sugar Suppl.	Lot V Corn Silage Molasses Suppl.	Lot VI Alfalfa Hay
	WINTERING RATION					
	Daily, lb.	Daily, lb.	Daily, lb.	Daily, lb.	Daily, lb.	Daily, lb.
Ground corn cobs[1]	2.82	3.06	....	....	....	....
Corn silage[1]	....	....	7.90	8.70	8.70	....
Alfalfa hay[1]	....	....	....	....	....	5.23
Minerals[2]	free choice	free choice	free choice	free choice	free choice	free choice
Supplemental mixture						
Soybean oil meal[3]	.35	.35	....	.35	.35	....
Corn sugar[4]	.10	....	....	.10	....	....
Dried brewer's grains	.20	....	....	.20	....	....
Brewer's grain with molasses[5]	....	.30	....	....	.30	....
Steamed bone meal	.05	.05	....	.05	.05	....
Iodized salt	.03	.03	....	.03	.03	....
Vit. A and D Conc.[6]	.0033	.0033	....	.0033	.0033	....

Lots I and II were fed one-half pound of shelled corn per ewe daily in addition to the Supplement to adjust the energy.

	Ewe Performance					
No. of ewes at start	25	25	25	25	25	25
No. of ewes at end	25	25	25	25	25	25
Initial weight, lb.	159	159	159	159	159	159
Pre-parturient weight, lb.	181	191	163	200	196	190
Parturient weight loss, lb.	21	24	22	27	22	21
Wool clip, lb.	8.9	9.3	7.9	8.8	9.5	9.1
No. of ewes that lambed	25	23	24	25	24	25
No. of lambs dropped	44	37	34	41	37	35
Percent lamb crop (dropped)	176	161	142	164	154	140
Percent lamb crop to June 17, 1953, per ewe lambing	160	126	125	132	142	136
Av. birth weight, lb.	9.6	10.4	9.8	11.2	11.2	10.4
Av. daily gain to June 17, lb.	.59	.68	.64	.69	.67	.71

[1] All roughages were fed free choice.
[2] Minerals consisted of 2 parts steamed bone meal and 1 part cobalt salt. (One ounce cobalt sulfate per 100 pounds plain salt).
[3] Solvent extracted soybean oil meal.
[4] Cerelose.
[5] 66⅔ percent molasses dried on brewers' grains.
[6] 10,000 I. U. of vitamin A and 1250 I.U. of vitamin D per gram.

Trial III—1952–53

Lot I. Ground corn cobs, Ewe Supplement I, (table 3) shelled corn.

Lot II. Ground corn cobs, Ewe Supplement II, shelled corn.

Lot III. Corn silage.

Lot IV. Corn silage, Ewe Supplement I.

Lot V. Corn silage, Ewe Supplement II.

Lot VI. Alfalfa hay.

All lots received the free choice mineral mixture listed in Trial II.

Results

Trial I

The results of this trial are summarized in table 1. No difference was recorded in average weight gain between the four lots of ewes up to the last pre-partum weighing. The alfalfa meal-fed ewes did not suffer as great weight loss during parturition (16 lb. per ewe) as ewes in any of the other three lots (25 to 32 lb. per ewe).

Wool clip averaged from 2 to 2.6 pounds heavier per ewe in the lot receiving alfalfa meal.

The percent lamb crop dropped ranged from 145 to 172 while the percent lamb crop weaned ranged from 103 to 117. The higher percentages were observed in the vitamin B_{12} supplemented lot.

Average birth weight of the lambs ranged from 10.0 to 10.6 pounds between the four lots. No differences in average daily gain between the four lots of lambs were found up to the time the lambs were turned onto pasture or until the lambs were marketed.

Trial II

This phase of the trial is summarized in table 2. Silage ewes lost less weight (6 to 8 pounds) at lambing than did the cob-fed lots (12 to 13 pounds). The corn silage lot ewes sheared more wool (.9 to 1.3 pounds) than the cob lots ($P < 0.01$).

The only significant difference found between the birth weight of lambs was between Lot III and Lot I ($P < 0.01$), and Lot III and Lot IV ($P < 0.05$). Outhouse (1950) has shown that a roughage ration of corn silage will produce larger lambs at birth than U.S. No. 2 clover-timothy mixed hay.

It was observed in the first trial that there was an apparent benefit from the addition of vitamin B_{12} to a corn cob supplemented ration in terms of number of lambs dropped and weaned. However, the addition of vitamin B_{12} to a similar ration in Trial II had no beneficial effect. Further investigation concerning the importance of additional vitamin B_{12} to ewe rations is needed to clarify this point.

The average daily gains of lambs from ewes on the roughages in Trial II were very similar (0.41 to 0.45 pound per day). The rate of mortality was aggravated by the onset of stiff lamb disease which affected most of the fastest growing lambs at 2–3 weeks of age.

Trial III

The data as summarized in table 3 show that the weight loss of the ewes at lambing was approximately equal in all lots. The supple-

mented corn silage lots averaged a heavier fleece weight than the cob lots, however, the differences were not statistically significant except between Lots I and V ($P < 0.05$).

Supplemented corn silage ewes produced lambs which were larger at birth than ewes in other lots. However, the lambs from the alfalfa hay lot appeared healthier and more vigorous as indicated by the lower death rate.

Lambs from alfalfa hay lot ewes gained at a faster rate (0.02 to 0.12 pound per day) than any of the lambs from ewes in the other lots.

Discussion

The results of the three trials reported in this paper indicate pregnant ewes in dry lot may be wintered successfully on ground corn cobs as the only roughage when a supplement containing protein, a small amount of energy, simple minerals and vitamin A and D concentrate is added.

Corn silage as the only feed was insufficient whereas adding a supplement to either corn silage or grass silage as the only source of roughage proved adequate.

Good quality alfalfa hay or dehydrated alfalfa meal, however, contributed something to the well-being of pregnant ewes which was not contained in the diets of ewes receiving no alfalfa hay or dehydrated alfalfa meal.

Summary

Three experiments are reported in which ground corn cobs, corn silage, grass silage, or alfalfa hay was fed as the sole source of roughage to pregnant ewes in dry lot. Rations were balanced by the addition of protein and energy feeds.

There was no consistent beneficial effect from the addition of B-complex vitamins including B_{12} to supplemented corn cob rations.

Supplemented corn silage ewes produced heavier fleece weights than ewes fed a ration of corn cobs and supplement or alfalfa hay during gestation and lactation.

Ewes fed supplemented corn silage produced larger lambs at birth than ewes on rations of corn cobs and supplement, grass silage and supplement, and corn silage or alfalfa hay alone. However, lambs from alfalfa hay-fed ewes had a lower rate of mortality.

Ewes fed supplemented corn cobs produced satisfactory lambs as indicated by birth weight and rate of gain.

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ANTIBIOTIC PELLET IMPLANTS FOR SUCKLING LAMBS[1]

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METHODS of administering antibiotics other than *per os* have been investigated since the growth stimulating property of certain antibiotics was first demonstrated. One such method consists of the implantation of antibiotic pellets subcutaneously (Noland *et al.*, 1952). The hypothesis has been advanced that pellets so placed may be absorbed slowly and thus exert their effect over a relatively long period of time.

The objective of this trial was to study the effect of implanting antibiotic pellets subcutaneously in the neck region of young suckling lambs.

Materials and Methods

Trial I. 1952

Lambs from the experimental flock of crossbred range ewes were selected randomly, without respect to sex or birthweight, at approximately two days of age to serve either as control or treated animals. The lambs were dropped in dry lot in late February and March and stayed there until pasture in May. No creep was provided on pasture, but equal parts shelled corn and whole oats were provided in the creeps in dry lot. Treated animals were implanted subcutaneously in the neck region with either two or four antibiotic pellets. Two types of antibiotic pellets were used. One type pellet contained 22 mg. of bacitracin (1000 units) and the other type pellet contained 11 mg. of bacitracin and 4.7 mg. of 1-ephenamine penicillin G (500 units bacitracin and 5000 units compenamine). This means there were actually six groups of lambs according to treatment: two groups of controls; two groups implanted with two and four pellets, respectively, containing 22 mg. bacitracin per pellet; two groups implanted with two and four pellets, respectively, containing 11 mg. bacitracin and 4.7 mg. 1-ephenamine pennicillin G per pellet.

Trial II. 1953

Two groups of experimental lambs of the same source listed for Trial I were used in this trial.

One group was divided randomly as each lamb was two days of

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age and one-third of the lambs served as control and was not implanted. One-third of the lambs was implanted with six pellets containing 22.5 mg. bacitracin per pellet, and one-third of the lambs was implanted with 7 pellets containing 20 mg. of aureomycin per pellet.

The second group was not put on treatment until the lambs were

TABLE 1. ANTIBIOTIC PELLET IMPLANTS FOR SUCKLING LAMBS

Treatment	No. Lambs	Av. Initial Wt., lb.	Av. Final Wt., lb.	Av. Daily Gain, lb.
1952—Implanted at two days of age with bacitracin				
Control	13	10.6	77.7	0.38
Two pellets bacitracin [1]	12	9.3	77.3	0.38
Four pellets bacitracin [2]	19	10.1	79.0	0.39
1952—Implanted at two days with bacitracin-penicillin combination				
Control	16	10.2	78.8	0.39
Two pellets bacitracin-penicillin [3]	16	10.4	81.8	0.41
Four pellets bacitracin-penicillin [4]	15	10.3	80.3	0.40
1953—Implanted at two days of age with aureomycin or bacitracin				
Control	66	10.7	70.8	0.68
Seven pellets aureomycin [5]	65	10.4	69.3	0.66
Six pellets bacitracin [6]	63	10.8	70.4	0.67
1953—Implanted at average 44 days of age with aureomycin				
Control	24	36.8	83.3	0.54
Seven pellets aureomycin [7]	25	37.9	81.6	0.51

[1] Twenty-two mg. bacitracin per pellet—44 mg. total dose.
[2] Twenty-two mg. bacitracin per pellet—88 mg. total dose.
[3] Eleven mg. bacitracin and 4.7 mg. 1-ephenamine penicillin G per pellet—22 mg. bacitracin and 9.4 mg. 1-ephenamine penicillin G total dose.
[4] Eleven mg. bacitracin and 4.7 mg. 1-ephenamine penicillin G per pellet—44 mg. bacitracin and 18.8 mg. 1-ephenamine penicillin G total dose.
[5] Twenty mg. aureomycin per pellet—140 mg. total dose.
[6] Twenty-two mg. bacitracin per pellet—132 mg. total dose.
[7] Twenty mg. aureomycin per pellet—140 mg. total dose.

older and heavier. One-half of this group served as control and was not implanted, whereas the other one-half was implanted with 7 pellets containing 20 mg. aureomycin per pellet when the lambs were of an average age of 44 days and averaged 38 pounds liveweight.

Results and Discussion

The implantation of lambs at two days of age with antibiotic pellets containing either bacitracin alone or bacitracin in combination with penicillin had no significant effect on growth rate (table 1). Similarly,

the implantation of lambs at two days of age or at an average of forty-four days of age with pellets containing aureomycin hydrochloride had no effect on growth rate. These results are in agreement with those of Perry *et al.* (1953) obtained from the implantation of pigs at two days of age. This treatment had no effect on 42-day weaning weights nor on subsequent feed lot performance of the pigs.

The results of this trial and the results reported by Perry *et al.* (1953) with pigs would indicate that the type of antibiotic pellets used in this experiment is not effective in improving the growth rate of suckling lambs significantly.

Summary

The subcutaneous implantation of lambs at two days of age with antibiotic pellets had no significant effect on growth rate when the following antibiotic implantations were made: 44 mg. bacitracin; 88 mg. bacitracin; 22 mg. bacitracin and 9.4 mg. penicillin; 44 mg. bacitracin and 18.8 mg. penicillin; 140 mg. aureomycin hydrochloride; 132 mg. bacitracin.

Similarly, no effect on growth rate was shown when lambs at an average age of 44 days were implanted with a total of 140 mg. aureomycin per lamb.

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SOME MINERAL CHANGES IN THE SKELETAL AND HEART MUSCLES OF VITAMIN E DEFICIENT LAMBS[1]

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FENN and Goettsch (1937) showed that nutritional muscular dystrophy in the rabbit was associated with a gain of chloride and a corresponding loss of potassium, magnesium and creatine in the muscle. They also found high concentrations of calcium and total phosphorus in muscles showing histological evidence of calcification.

Since Culik *et al.* (1951) and Bacigalupo *et al.* (1952) described the occurrence of muscular dystrophy in lambs fed a vitamin E-free diet, it seemed possible that certain changes in the composition of the muscles could accompany the histo-pathological alterations produced by vitamin E deficiency. Thus, the present paper, a continuation of the previously mentioned studies, is a report of the changes in the content of sulfated ash, total sodium, potassium, calcium, magnesium and phosphorus in dystrophic skeletal and heart muscles from vitamin E deficient lambs.

Experimental

The material used in the chemical analysis was obtained from the experiments on vitamin E deficiency carried out by Culik *et al.* (1951) and Bacigalupo *et al.* (1952). The thigh muscles and part of the ventricles of the lamb's heart were removed at the time of necropsy, placed in tightly sealed jars, and stored at low temperature (—20° C.) for two or three months. After this time, the samples were thawed and prepared immediately for analysis.

For the chemical analysis the muscle samples were ashed in the following manner. The heart and thigh muscles were freed of the muscular sheaths, tendons and fat. Then they were cut in small pieces and a sample of about 10 gm. was placed in previously weighed crucibles and the whole weighed. The crucibles were heated first on a hot plate and later with the free flame of a bunsen burner. The dry residue was treated with a few drops of concentrated nitric and

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sulfuric acid, and the crucibles placed overnight in a muffle furnace, regulated to give a maximum temperature of 500° C. The sulfated ash was determined. Then 5 ml. of concentrated HCl was added to the ash, boiled for one minute and the solution filtered through ash-free filter paper.

An aliquot of the solution was employed for the calcium determination which was carried out according to the method of Shohl (1922). The supernatant solution left after the precipitation of the calcium oxalate was used for the determination of magnesium, which was carried out by the method of Briggs (1924). Other aliquots were taken for the determination of potassium and sodium using the flame photometer method (Anonymous, 1949). Wet-ashed samples of muscles were employed for the determination of phosphorus, which was done by the method of Fiske and Subbarow (1925).

Results and Discussion

Results of the mineral analysis are summarized in table 1. The most significant changes in the composition of the skeletal muscles of vitamin E deficient lambs were the lower potassium content and the higher sodium content in comparison with the normal controls. The calcium content of the skeletal muscles of vitamin E deficient lambs was significantly higher than the calcium content of positive control lambs. However, the calcium content of the skeletal muscles of vitamin E deficient lambs was quite variable (table 1). Other changes produced by vitamin E deficiency were slight decreases in the magnesium and phosphorus content of skeletal muscles.

Analysis of muscle samples from lambs in which symptoms of muscular dystrophy had been produced and had subsequently been treated with therapeutic amounts of dl-α tocopherol acetate, indicated a return to normal levels of the minerals studied. This suggests that the mineral changes produced by vitamin E deficiency are reversible.

These findings indicate that dystrophic skeletal muscles of lambs undergo similar changes in the content of sodium, potassium and calcium as dystrophic muscles of the rabbit (Fenn, 1937). The total phosphorus content of muscles from E deficient lambs was not altered. This agrees with the findings of Weissberger and Harris (1943) for the vitamin E deficient rat. However, Fenn and Goettsch (1937) have reported an increase in the total phosphorus content of dystrophic muscles of rabbits.

TABLE 1. AVERAGE MINERAL CONTENT OF MUSCLES FROM ANIMALS FED DIETS WITH AND WITHOUT VITAMIN E [1]

Diet	No. of Lambs	Sulfated Ash %	Na mg./100 gm.	K mg./100 gm.	Ca mg./100 gm.	Mg mg./100 gm.	P mg./100 gm.
			Skeletal Muscles (Thigh)				
Basal [2]	11	1.5±0.18 [3]	159.4± 8.25	198.9±10.94	42.2±10.18	21.9±2.32	247.2±15.96
Basal+E (controls)	7	1.4±0.63	91.3± 9.30	287.2±18.39	7.0± 0.76	31.3±3.20	268.1± 7.52
Basal+E (recovery)	3	1.4±0.19	127.5± 4.04	262.4±31.82	8.8± 0.73	20.1±3.08	267.6±22.61
			Heart Muscle				
Basal	7	1.4±0.13	143.6±17.89	181.7±19.41	23.3± 8.36	18.8±2.32	343.3±12.85
Basal+E (controls)	3	1.3±0.04	120.0±11.80	226.0±11.50	6.3± 0.16	27.6±7.53	261.0± 4.65
Basal+E (recovery)	1	1.6	225.2	294.8	8.8	24.9	250.1

[1] All values for Na, K, Ca, Mg and P are expressed as mg./100 gm. of muscle (wet basis).
[2] Purified E low diet containing either commercial or molecular distilled lard (Culik *et al.*, 1951).
[3] Standard error of the mean.

In the heart muscles, high levels of calcium and phosphorus were the most marked changes that occurred in vitamin E deficiency (table 1). The level of total calcium and phosphorus was 23.3 and 343.3 mg. per 100 gm. respectively.

The changes of sodium and potassium in the heart muscle followed a pattern similar to those in skeletal muscles, but were not as marked.

Comparing the effects of vitamin E deficiency on the mineral composition of skeletal and heart muscles, it can be observed that the former is affected more severely than the latter.

Inasmuch as field cases of "stiff-lamb" disease have been cured by the administration of vitamin E it is generally assumed that this disease is due to E deficiency. However, since experimentally produced vitamin E deficiency results in marked changes in the sodium, potassium and calcium content of dystrophic skeletal and heart muscles, it is interesting to speculate on the possibility that dietary imbalances of these minerals might also induce symptoms of "stiff-lamb" disease.

Summary

Skeletal and heart muscles from lambs fed vitamin E deficient and E supplemented diets have been analyzed for several inorganic elements. The results of these analyses revealed that skeletal muscles from vitamin E deficient lambs had a higher concentration of sodium and calcium and a lower concentration of potassium than skeletal muscles from control lambs. Heart muscle from E deficient lambs contained more calcium and phosphorus than those from control lambs.

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RESPONSE OF LAMBS FED VARIED LEVELS OF ELEMENTAL SULFUR, SULFATE SULFUR AND METHIONINE [1, 2, 3]

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IT has been established that the ruminant is capable of converting inorganic sulfur to protein sulfur, Starks *et al.* (1953), Hale and Garrigus (1953), Block *et al.* (1951), Thomas *et al.* (1951), Block and Stekol (1950), and Loosli *et al.* (1949). However, none of these workers determined whether the conversion of the inorganic sulfur to protein sulfur was sufficient to permit optimum growth. Loosli *et al.* (1949) showed that the ten essential amino acids are synthesized in significant amounts in ruminants fed urea as the only source of nitrogen. Thomas *et al.* (1951) failed to maintain life in lambs fed a sulfur deficient ration. When this ration was supplemented with sulfate salts the lambs gained about 0.2 lb. daily for an 80-day period. The gain obtained indicates that the lambs made good use of the added sulfur, but a 0.2 lb. gain cannot be considered optimum for lambs. Starks *et al.* (1953) using the paired feeding technique demonstrated that elemental sulfur supplementation of a sulfur deficient ration caused a significant increase in nitrogen retention. Since the lambs were pair fed, it was impossible to determine if optimum growth could be obtained.

With the above information available the present experiment was conducted in order to study further the utilization of inorganic sulfur and urea nitrogen in the nutrition of growing lambs; to compare the utilization of elemental sulfur, sodium sulfate and DL-methionine; and to study the quantitative requirements of the three compounds for growing lambs.

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[2] This is a fifth paper in a series on sulfur in sheep nutrition.

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Experimental

Growth studies employing individual feeding as the primary tool were used in evaluating the various forms of dietary sulfur in a purified lamb ration. Observations were also made upon wool growth and blood urea during the course of the growth studies as well as histological examination of the lamb carcasses following slaughter.

Thirty grade, black-faced, wether lambs and ten grade, black-faced, ewe lambs approximately three and one-half months of age and weighing between 37 to 59 pounds each were divided at random into ten treatments of four lambs each. The lambs were then allotted at ran-

TABLE 1. BASAL RATION

Ingredient	Percent
Corn starch	35.4
Cerelose	22.5
Wheat straw	15.0
Wood flock	15.0
Corn oil	3.5
Wheat germ oil	0.5
Urea (crystalline)	4.0
Choline chloride	0.1
Minerals [1]	4.0
Vitamins A, D, Thiamin and Riboflavin [2]	+

[1] Minerals—carbonate mix of Thomas *et al.* (1951).

[2] Vitamins—viadex guaranteed to contain 4000 U.S.P. units of vitamin A and 750 U.S.P. units of vitamin D per gram was fed at the rate of one gram per pound of ration. Thiamin and riboflavin were fed at the rate of one mg. of each per pound of ration.

dom into individual pens in a shed open to the south where they were housed throughout the experiment (70 days: May 26—August 4). The pens, approximately four feet square, were separated by half-inch mesh wire and were bedded with shavings. To control flies the area was sprayed periodically.

The lambs were fed *ad libitum* the basal purified ration shown in table 1, and this ration supplemented with three graded levels each of elemental sulfur, sodium sulfate, and DL-methionine. The sulfur and nitrogen content of all rations is given in table 2. The procedures used for these determinations were the same as those described by Starks *et al.* (1953). Feed and water were kept before the lambs at all times. The lambs were weighed and individual feed intakes were recorded every two weeks.

At the beginning of the test period, a wool sample was clipped from each lamb beginning at the center of the back just forward of the

rear rib and extending downward about 14 cm. A small animal clipper which gives a 4 cm. cut was used. This sample was used to adjust the weight of the wool grown during the experimental period since the exact ages and prior nutrition of the lambs were known. Total nitrogen content was also determined and compared with the nitrogen content of the wool grown during the experimental period. Wool was then clipped from approximately 5 sq. in. of this rib section to permit sampling of wool grown during the test period. After 56 days on the test ration wool was clipped from approximately 50 sq. cm. of this area. The methods used in scouring, drying, weighing,

TABLE 2. COMPOSITION OF RATIONS (BY ANALYSIS)

Ration [1]	Total Sulfur	Total Nitrogen	Ratio N:S
	%	%	
Basal	0.054	2.04	37.8
Basal+0.2 % S	0.213	2.06	9.7
Basal+0.4 % S	0.432	2.09	4.8
Basal+0.6 % S	0.606	2.17	3.6
Basal+0.89% SO_4	0.244	2.07	8.5
Basal+1.33% SO_4	0.303	2.03	6.7
Basal+1.78% SO_4	0.383	2.02	5.3
Basal+0.2 % M	0.103	2.06	20.0
Basal+0.5 % M	0.138	2.11	15.3
Basal+0.7 % M	0.161	2.16	13.4

[1] S=Elemental sulfur; SO_4=Sodium sulfate; M=DL-methionine.

and nitrogen analysis are the same as those previously described, Starks *et al.* (1953).

Gain in weight and wool growth were analyzed according to the method of covariance (Snedecor 1946). Difference in nitrogen content of the initial and 56-day wool growth were analyzed by the t-test for paired differences (Student 1908). At the termination of the feeding trial 28 of the lambs were slaughtered by a local packing plant and sections of heart, liver, and kidney were taken from 20 of the lambs.

Histological examination of these sections was made together with tissues taken from two basal and two sulfate lambs which were killed and autopsied at the University of Illinois Veterinary Laboratory. The tissues were fixed in Bouin's solution and embedded in paraffin by the usual histological technique. The slides were stained with Harris' hematoxylin and eosin.

According to the method of Van Slyke and Cullen (Hawk *et al.* 1949), blood urea was determined on 16 of the lambs at the start of the experiment, at 13 days and again at the 53rd day of the experiment. The lambs included in this study were four basals and the 4 lambs on the highest sulfur supplement within each sulfur compound.

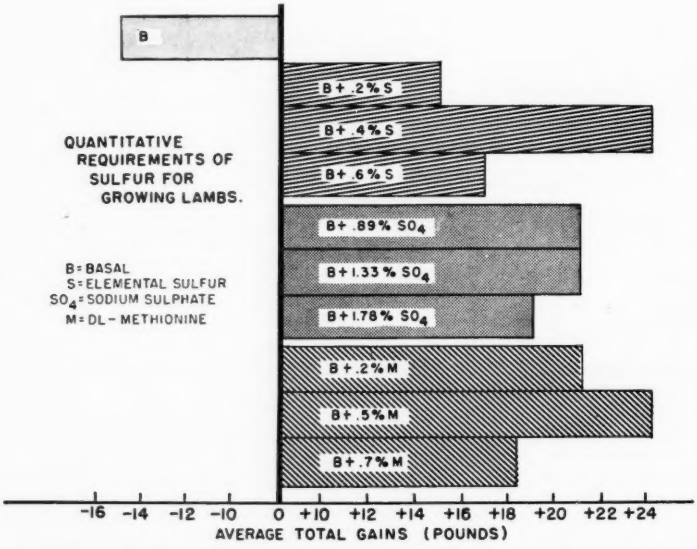

Figure 1. Comparison of average growth response of lambs receiving a basal purified ration, low in sulfur, to that of lambs receiving the basal ration supplemented with three levels each of elemental sulfur, sodium sulfate, and DL-methionine.

Results and Discussion

A graphic representation of the effect of the various sulfur compounds on the weight gain of the lambs is shown in figure 1. In table 3 total weight gains, rate of gain, feed efficiency and wool growth data are presented. The lambs receiving the sulfur deficient basal ration lost weight throughout the trial. This is in agreement with Starks *et al.* (1953) and Thomas *et al.* (1951) who were unable to maintain the weight of lambs receiving a similar ration. This demonstrates that lambs are unable to maintain their weight in the absence of some form of sulfur.

TABLE 3. EFFECT OF VARIOUS SULFUR COMPOUNDS ON WOOL GROWTH, WEIGHT GAINS, AND FEED EFFIENCY OF LAMBS[1]

Treatment [2]	Number of Lambs Completing Test	Wool Growth [3] per 10 sq. cm. for 56 Days	Total Average Gain	Average Daily Gain	Feed Required per Pound Gain
		gm.	lb.	lb.	lb.
Basal	2 [4]	0.217	−14.0	−0.20	....
Basal+0.20% S	3	0.292	15.3	0.22	10.5
Basal+0.40% S	2	0.289	24.0	0.34	7.4
Basal+0.60% S	3	0.322	17.3	0.25	9.4
Basal+0.89% SO_4	3	0.303	21.0	0.30	9.3
Basal+1.33% SO_4	3	0.305	21.3	0.31	8.2
Basal+1.78% SO_4	4	0.347	19.3	0.28	9.7
Basal+0.20% M	4	0.330	21.5	0.31	8.6
Basal+0.50% M	3	0.285	24.0	0.34	7.8
Basal+0.70% M	4	0.352	18.3	0.26	9.1

[1] No growth data included for the lambs that failed to finish the 70-day trial.
[2] See table 2 for description of treatment.
[3] No wool data are included for lambs that remained on test for less than 56 days.
[4] One of the basals died at 53 days and a second at 58 days.

Figure 2 shows a representative group of the lambs at the 63rd day of the trial. These lambs received the lowest level of each sulfur supplement. The lamb fed the basal ration was very weak and barely able to stand when this picture was taken. Two lambs on the basal ration had died and the fourth (not shown in this picture) lost 15 pounds during the experiment.

In contrast to the performance of the lambs on the basal ration, those which received sulfur (regardless of form) gained weight. The weight gains of the sulfur treated lambs [6] were significantly greater

Figure 2. Lambs, left to right, received 0.2 percent DL-methionine, 0.89 percent sodium sulfate, 0.2 percent elemental sulfur and basal. (Sixty-third day of experiment.)

[6] Includes lambs receiving sulfur in the form of elemental sulfur, sodium sulfate and DL-methionine.

than those on the basal ration ($P < 0.001$). The weight gains and feed consumption analyzed according to the method of covariance (Snedecor 1946) showed that there was no significant difference in the average gain or feed consumption between the sulfur treatments. Also there was no difference in weight gains between levels of sulfur supplementation within each treatment. It is interesting to note, however, that the lambs on the 0.4 percent elemental sulfur, the 1.33 percent sodium sulfate, and the 0.5 percent DL-methionine made the most rapid and efficient gains although the differences were not statistically significant.

The weight gains suggest that any of the three sulfur compounds tested are of equal efficiency in supplementing a sulfur deficient ration. However, if the number of lambs from each treatment finishing the experiment is taken into consideration the efficiency of the various sulfur compounds appears to be different.

Only 8 out of 12 of the elemental sulfur supplemented lambs finished the trial. Two of the lambs refused to eat the ration and had to be removed after 14 and 18 days on trial. Two more of the sulfur supplemented lambs stopped eating and had to be removed from the experiment after 53 and 56 days. It is well known that elemental sulfur is unpalatable to sheep in relatively large amounts and it has been used in the feed lot to control feed intake of full-fed lambs (Christensen *et al.*, 1947). Also there are reports of elemental sulfur toxicity to the point of causing death (Steyn 1931). However, in the present experiment those elemental sulfur supplemented lambs that finished the trial made satisfactory gains with the exception of one lamb.

Only two of 12 sodium sulfate supplemented lambs failed to finish the experiment. These two lambs were removed after 63 and 65 days on the experiment because of failure to eat. The 1.78 percent sodium sulfate was probably too high because the feces from the lambs receiving this level were very moist and soft. Feed consumption and weight gains do not suggest that this high level is toxic.

In contrast, all but one of the methionine lambs finished the trial and there was no indication at the end of the experiment that they were going off feed. This lamb was removed after 5 days on the experiment, and its removal was not associated with treatment.

The data presented in table 3 suggest that under conditions of the experiment the lowest level of each of the three sulfur compounds tested approached the sulfur requirement of growing lambs. The ration with the lowest level of methionine (0.2 percent) contained

only 0.103 percent total sulfur. The lambs on this level of methionine made gains statistically as satisfactory as the lambs receiving higher levels of methionine. The nitrogen:sulfur ratio of the 0.2 percent methionine ration is 20:1. This is wider than the 15:1 ratio recommended for ruminants (Loosli 1952). However, the total nitrogen content of this ration (2.06 percent) may be higher than required for optimum growth of lambs this size. The nitrogen:sulfur ratios of rations fed to the elemental sulfur and sodium sulfate supplemented groups are narrower than 15:1.

The response of the lambs to supplementation of a sulfur deficient ration indicates that the lambs utilized the inorganic sulfur well. The average weight gain of the sulfur supplemented lambs was 0.29 pound per day which can be considered a good gain for lambs of this size and age on the type of ration that they received. The maximum rate of conversion of the inorganic sulfur to amino acid sulfur cannot be estimated from this trial. Starks (U. of I. thesis) found a 50 percent digestibility of elemental sulfur when it had been added at a level of 3 grams per pound of a sulfur deficient ration.

As high as 92 percent of the total nitrogen of these rations were supplied by urea. The excellent growth obtained together with the feed efficiency values suggests that the urea was well utilized. To the writers' knowledge this is the best growth rate that has been obtained with growing lambs when nearly all of the dietary nitrogen was supplied in the form of urea.

Wool was produced by the lambs on the basal ration although they were losing weight, however, significantly less was produced than by the sulfur supplemented lambs ($P < 0.001$) (includes all three sulfur compounds). This is in agreement with Starks *et al.* (1953), Thomas *et al.* (1951) and Garrigus *et al.* (1950) where it was found that wool growth was greater when a sulfur deficient ration was supplemented with some form of sulfur. In this trial there was no difference in wool growth produced between the sources or levels of sulfur.

The average nitrogen composition of the pre-experimental wool growth was greater than that grown during the test period ($P < 0.01$). This is in agreement with Starks *et al.* (1953) and Thomas *et al.* (1951). At this time there is no explanation for this difference in the nitrogen composition of the two wool samples.

Blood urea values for the 48 determinations ranged from 14.25 to 28.50 mg. percent. The average values for the three separate samplings were 21.87, 20.88, and 21.35 mg. percent respectively. There was no suggestion that the high intake of urea on these rations had

any effect on blood urea. This is not in agreement with Dinning *et al.* (1949) who observed that urea feeding increased blood urea values.

Some abnormal histological conditions were found in the tissues studied. No significant difference between treatments was found. The heart muscle appeared normal in 14 of 17 lambs; however, the following histological condition was noted in No. 313, a lamb receiving 0.89 percent sodium sulfate: degeneration of muscle fibers, proliferation of fibroblasts, and infiltration with lymphocytes, macrophages and neutrophils. The heart muscle of Nos. 102 and 104 (basals) showed a little myocardial degeneration, proliferation of fibroblasts, and limited lymphatic infiltration. In addition No. 104 showed infiltration with lymphocytes, macrophages, and neutrophils.

Histological examination showed the kidney to be normal in most cases; however, lambs Nos. 432 and 234, receiving 0.7 percent methionine and 0.6 percent elemental sulfur respectively, showed a few proliferative changes in the glomeruli with the glomerulus filling the cavity.

Of 19 livers examined 7 showed appreciable vacuolation of fat in the periphery of the lobules. This condition was observed in lambs on the basal ration, and the basal ration supplemented with elemental sulfur, sodium sulfate, and DL-methionine.

Summary

An experiment is reported in which forty growing-fattening lambs were fed a purified ration (consisting primarily of wood cellulose, wheat straw, starch, cerelose, and urea) to study the utilization of inorganic sulfur and urea nitrogen in the nutrition of lambs. The basal ration, containing 0.054 percent sulfur with 92 percent of the nitrogen from urea, was supplemented with three gaded levels each of elemental sulfur (0.2%, 0.4% and 0.6%), sodium sulfate (0.89%, 1.33% and 1.78%), and DL-methionine (0.2%, 0.5% and 0.7%).

Weight gains and wool growth were increased by the addition of the sulfur supplements. This increase was highly significant ($P < 0.001$). There was no statistically significant difference among the sulfur sources or levels within each source.

The lambs receiving the basal ration lost weight throughout the trial. One died at 53 days and a second at 58 days. The rations having the lowest level of each sulfur supplement (0.2 percent elemental sulfur, 0.89 percent sodium sulfate, and 0.2 percent DL-methionine)

furnished adequate or nearly adequate sulfur as judged by gain in weight and wool growth.

Under the conditions of this experiment the high levels of urea fed apparently had no effect on blood urea levels.

The efficiency of the three sulfur supplements is briefly discussed.

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FURTHER STUDIES ON THE AVAILABILITY OF PHOSPHORUS IN ALFALFA HAY [1]

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University of California [2]

In earlier studies (Lofgreen and Kleiber, 1953) it was found that 91 percent of the phosphorus in alfalfa hay was absorbed by lambs. The method involved labeling the body phosphorus with radioactive phosphorus, P^{32}, and determining what proportion of the fecal phosphorus originated from the labeled body phosphorus. The formula developed for calculating the proportion of metabolic phosphorus in the feces is

$$M=\frac{\phi'(t+1)}{\pi(t)} \tag{1}$$

where $\pi_{(t)}$ is the specific activity of the plasma inorganic phosphorus (plasma trichloracetic acid filtrate) at time t and $\phi_{(t+1)}$ is the specific activity of the fecal phosphorus one day later. In these studies, however, the numerous venous punctures necessitated by frequent injections of labeled phosphate and frequent blood sampling resulted in considerable discomfort to the animal and made it difficult to maintain a uniform feed intake. The frequent injections of P^{32} were made in an effort to establish a blood level which would remain in a nearly steady state during the collection period. Frequent blood samples were drawn so that the concentration of the isotope in the blood could be correlated with that in the feces one day later. If frequent injections could be obviated by making the injections subcutaneously and if the urine specific activity could be used as an indication of the specific activity of the plasma inorganic phosphorus (plasma TCF), as has been shown to be true for the rat (Hevesy, 1948) the necessity for numerous venous punctures would be eliminated and the method would lend itself very readily to routine use. Because there is little direct information on the availability of phosphorus in livestock feeds it seemed desirable to investigate these possibilities for improving the method of determining phosphorus availability. Furthermore, it seemed important that the availability of the phosphorus in a second sample of the alfalfa used in the earlier studies be determined since there is no other work to

[1] This study was partially supported by a grant from the United States Atomic Energy Commission.

[2] Department of Animal Husbandry, Davis.

which it can be compared and information is needed on the repeatability of the method.

Experimental

Four yearling wethers weighing from 80 to 88 pounds were fed a constant level of chopped No. 2 alfalfa hay for 14 days. The hay used was from the same lot as that used in the earlier studies (Lofgreen and Kleiber, 1953). At 10:00 A.M. on the first day each lamb was given one subcutaneous injection of approximately 4.5 millicuries P^{32} in a sterile isotonic solution of sodium phosphate. In an attempt to determine when the maximum concentration of P^{32} would appear in the plasma and when this maximum would be reflected in the feces and urine, blood samples were drawn at six and twelve hours after injection the first day and at 10:00 A.M. daily thereafter. Fecal and urinary excretions were also collected at 10:00 A.M. daily. Total phosphorus was determined in all samples by a wet ashing procedure (Koenig and Johnson, 1942; Kitson and Mellon, 1944) and the radioactivity measured by the procedure described by Kleiber *et al.* (1951).

Results and Discussion

The concentration of P^{32} in the plasma TCF, feces and urine of each animal is shown in figure 1. (Concentration of P^{32} is expressed herein as specific activity which is the number of microcuries of P^{32} per gram of total phosphorus.) The uniformity of the plasma and fecal levels among the four animals is noteworthy. In earlier studies it had been found that the maximum tracer concentration in the feces of lambs injected intravenously with P^{32} appeared the day following the maximum level in the plasma TCF. In all four lambs used in this study the maximum concentration of P^{32} in the plasma TCF occurred the first day. A peak in the fecal P^{32} concentration occurred in all four animals one day later and in the case of three of these this was the highest level reached. These data, therefore, confirm the earlier observation that the peak P^{32} concentration in the plasma TCF will be reflected in the feces one day later and lend support to the basic assumption that in sheep the metabolic phosphorus secreted into the gut during one day will appear in the feces the following day.

From the data in figure 1 it can readily be seen that from 1 to 14 days the specific activity of the urine cannot be used as a measure of that of the plasma TCF. It appears, therefore, that it will be necessary to sample the blood directly in future trials on phosphorus availability.

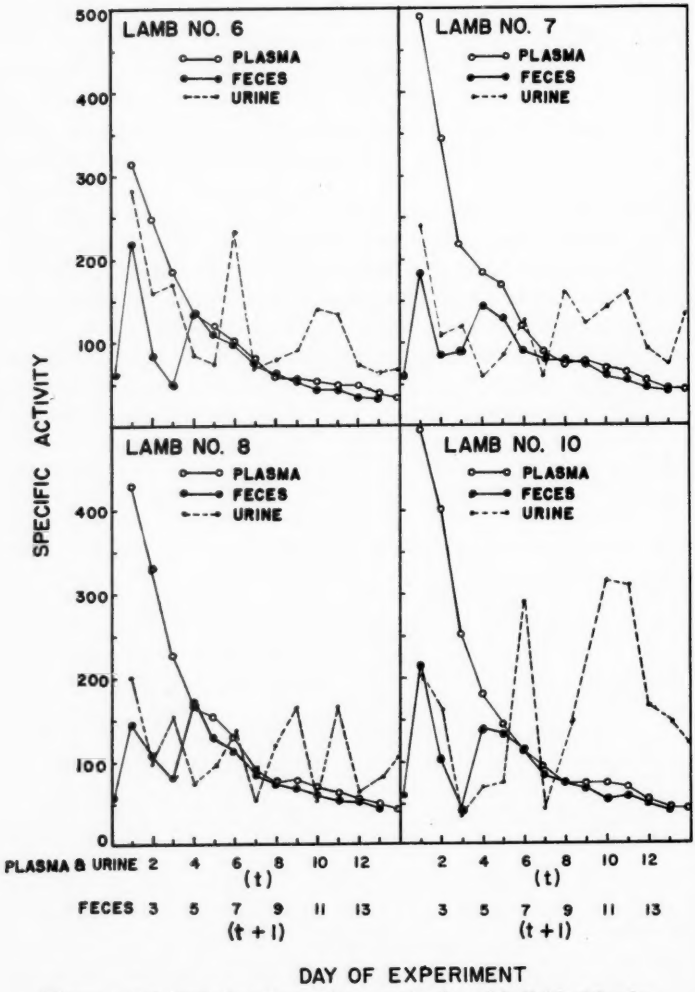

Figure 1. P^{32} levels in plasma, feces and urine of individual lambs.

It is interesting to note the very close correlation of the plasma and fecal specific activity after the fourth day. One could conclude from these data that a steady state had been reached in the various processes involved in the secretion of body phosphorus into the gut and that on

a uniform food intake this secretion occurred at a rather constant rate from day to day.

The appearance of the curves representing the plasma TCF and fecal P^{32} levels after the fourth day indicates that their relationship

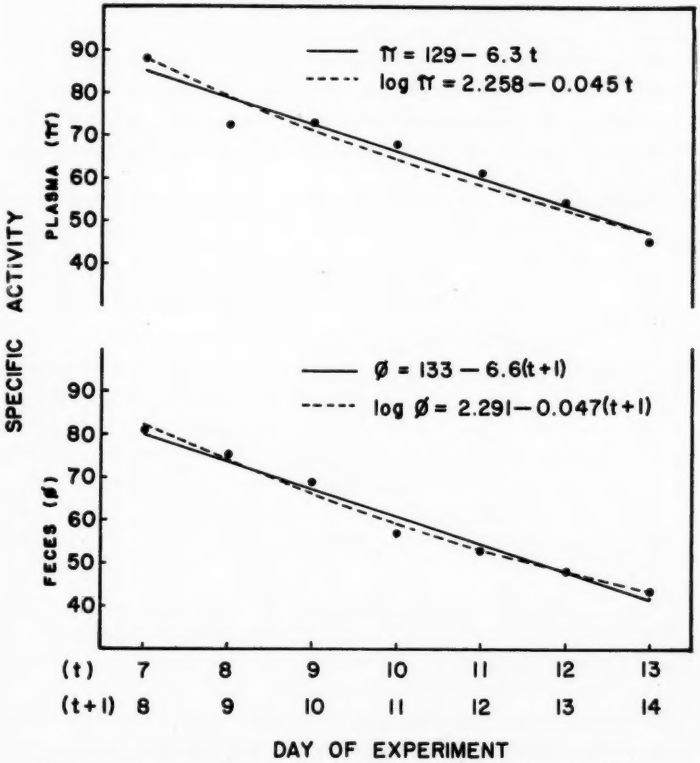

Figure 2. Average plasma and fecal P^{32} levels after the seventh day.

with time is a logarithmic function. From the seventh day, however, the relationship appears to be linear. In figure 2 the average plasma TCF and fecal P^{32} levels from the seventh day are plotted against time. In both cases the linear equation fits the data as satisfactorily as the logarithmic equation. From the standpoint of the routine use of this method for determining phosphorus availability it is a distinct advantage to use that period during which the plasma and fecal P^{32}

levels show a linear relationship with time. If the seven day period from the seventh to thirteenth day inclusive is used it appears that it may be possible to sample the blood on the seventh and thirteenth days and use the average of the two samples to represent the plasma TCF specific activity for the period. Since the metabolic phosphorus secreted into the gut during this period would appear in the feces from the eighth to fourteenth day inclusive the specific activity of the feces could be determined from a composite sample obtained during this period. Such a method would lend itself very readily to routine use.

In table 1 are shown the daily ratios of fecal specific activity to the plasma TCF specific activity the previous day for the four animals (M

TABLE 1. DAILY RATIOS OF THE FECAL SPECIFIC ACTIVITY (ϕ) TO THE PLASMA TCF SPECIFIC ACTIVITY (π)

Day After Injection (t)	Ratios of Fecal Specific Activity at (t+1) to the Specific Activity of the Plasma TCF at (t)			
	Lamb No.			
	6	7	8	10
7	0.99	0.88	0.95	0.89
8	1.08	1.08	0.98	1.02
9	0.98	0.96	0.90	0.94
10	0.88	0.87	0.85	0.75
11	0.89	0.88	0.86	0.86
12	0.76	0.85	0.97	0.93
13	0.93	1.00	0.89	0.94
Means	0.93	0.93	0.91	0.90

in equation 1). These ratios represent the proportion of the fecal phosphorus which is of metabolic origin. The ratio for each lamb as calculated from the average of the plasma TCF specific activity on the seventh and thirteenth days and from the fecal composite collected from the eighth to fourteenth day is shown in table 2. In the case of three lambs this ratio is identical to the mean of the daily ratios shown in table 1. The fourth is not markedly different. It does appear possible, therefore, that accurate determinations of the average metabolic phosphorus content of the feces can be made by the use of one subcutaneous injection of labaled phosphate, collection of blood samples on the seventh and thirteenth days and feces from the eighth through fourteenth days. When combined with a routine digestion trial such a method could yield valuable information on the availability of phosphorus in various feedstuffs.

TABLE 2. RATIOS OF FECAL SPECIFIC ACTIVITY TO PLASMA TCF SPECIFIC ACTIVITY CALCULATED FROM COMPOSITE FECAL SAMPLE AND PLASMA SAMPLED ON SEVENTH AND THIRTEENTH DAYS

Category of Interest	Lamb No. 6	7	8	10
Specific activity of plasma TCF on day 7	76.8	90.0	88.8	94.5
Specific activity of plasma TCF on day 13	39.9	46.4	49.7	45.5
Mean specific activity of plasma TCF for period (π)	58.4	68.2	69.3	70.0
Specific activity of fecal composite from eighth to fourteenth day (ϕ)	52.5	63.6	63.4	63.3
Ratio, ϕ/π	0.90	0.93	0.91	0.90

Table 3 presents the individual data on the division of fecal phosphorus into metabolic and unabsorbed feed phosphorus and the availability of phosphorus in the alfalfa hay. It is interesting and reassuring to note the good agreement between the results of the earlier trials wherein numerous intravenous injections were used and those reported here in which only one subcutaneous injection was made. In the earlier trials the average percentage of metabolic phosphorus in the feces was 88 percent and the true digestibility of the phosphorus averaged 91 percent. The respective values for the present trials are 92 and 94 percent. These results confirm the earlier observation that the phosphorus in this particular alfalfa hay was highly available for absorption by lambs.

TABLE 3. THE AVAILABILITY OF THE PHOSPHORUS IN ALFALFA HAY

Category of Interest	Lamb No. 6	7	8	10
Alfalfa dry matter consumed daily, gm.	1005	935	1005	935
Phosphorus consumed daily, gm.	2.53	2.36	2.53	2.36
Daily fecal phosphorus, gm.	1.59	1.69	1.74	1.69
Phosphorus apparently digested:				
Grams	0.94	0.67	0.79	0.67
Percent	37	28	31	28
Metabolic phosphorus:				
Percent of fecal phosphorus	93	93	91	90
Grams	1.48	1.57	1.58	1.52
Unabsorbed phosphorus, gm.	0.11	0.12	0.16	0.17
Absorbed phosphorus, gm.	2.42	2.24	2.37	2.19
True digestibility of phosphorus, percent	96	95	94	93

Summary

A method is described for determining the availability of the phosphorous in feedstuffs wherein only one subcutaneous injection of radioactive phosphorus need be made. From the seventh through thirteenth day the specific activity of the plasma inorganic phosphorus and the feces exhibit a linear relationship with time. This observation enables one to estimate the average specific activity of the plasma inorganic phosphorus by drawing blood samples on only the seventh and thirteenth days. The fecal specific activity is determined on a composite sample collected from the eighth through fourteenth day. The ratio of the specific activity of the fecal composite to the mean specific activity of the plasma inorganic phosphorus on the seventh and thirteenth days represents the proportion of the fecal phosphorus which is of metabolic origin.

Using this method it was found that approximately 92 percent of the fecal phosphorus of yearling wethers being fed alfalfa hay was of metabolic origin and 94 percent of the phosphorus consumed was absorbed. The result indicates a high availability of the phosphorus in alfalfa hay.

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THE EFFECT OF FAT-FREE DIETS ON LAMBS AND GOATS

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FATS have always been regarded as rich sources of energy but only during the last few decades have a growing number of reports appeared in the literature on the non-caloric value of fats. Of prime significance among these was the classical paper by Burr and Burr (1929) describing the effects of a fat deficiency in rats. The deleterious effects of low fat diets have since been reported in mice (White *et al.*, 1943), dogs (Hansen, 1943), chickens (Rieser, 1950), pigs (Witz and Beeson, 1951), humans (Hansen, 1933), and in some insects (Fraenkel and Blewett, 1945).

With the many solvent extracted feeds now appearing on the market, there arises the question as to whether ruminants require a dietary source of the essential fatty acids and if not, if the reason lies in rumen synthesis. The following experiments were conducted to determine if suckling and weanling ruminants require a source of dietary fat and if there is any appreciable rumen synthesis of the essential fatty acids.

Experimental

This study consisted of two experiments. In the first, six weanling lambs with an average weight of 26.4 kg. were arranged according to size, sex and condition into a control group of two and an experimental group of four. They were placed in individual pens bedded with wood shavings and gradually changed from a ration of good alfalfa hay and oats to the purified diets shown in table 1. The lambs were fed twice daily as much as they would consume without going "off feed". At 112 days, the alpha protein of both diets was replaced by a nitrogen equivalent of urea to insure a completely fat-free basal diet. The sheep were weighed every 5 days, blood samples were drawn from the jugular vein every 3 to 4 weeks and rumen samples were taken by stomach tube at varying intervals.

The lipids were extracted [1] from the blood and rumen samples and

[1] The lipids were extracted from 10 to 20 ml. of plasma by shaking for 15 minutes with an equal volume of absolute alcohol and 50 ml. of petroleum ether (60–70). Aliquots of the petroleum ether layer were evaporated in test tubes under nitrogen and reduced pressure and analyzed spectrophotometrically for linoleic, linolenic and arachidonic acids. Total lipids were secured by evaporating aliquots of the petroleum ether layer under nitrogen and reduced pressure in small 300 mg. aluminum dishes and weighing on a microbalance.

subjected to spectrophotometric analysis employing modifications of the method of Brice and Swain (1945). Dienoic, trienoic, and tetraenoic acids were calculated as linoleic, linolenic and arachidonic acids, respectively. Individual strains of bacteria [2] were isolated from the rumen of a cow receiving a natural diet and were grown in one to eight liter quantities of various low-fat and completely fat-free purified media. In order to secure a maximum yield of bacteria, the pH of the medium was restored to normal (6.7 to 7.0) every 12 hours with sodium bicarbonate and the organism cultured until it could no longer lower the pH. The bacteria were recovered by centrifugation, washed three times with saline and the lipids extracted with boiling alcohol-ether (3:1).

TABLE 1. COMPOSITION OF WEANLING LAMB DIETS IN EXPERIMENT I

Ingredient	Corn Oil Diet	Fat-Free Diet
Cerelose	51.5	53.0
Jelflake (cellophane)	30.0	30.0
Alpha protein [1]	12.0	12.0
Minerals [2]	5.0	5.0
Corn oil (Mazola oil)	1.5	0.0
Vitamins [3]	...	...
	100.0	100.0

[1] The Glidden Company, Chicago, Ill.
[2] Minerals: (%) NaCl, 12.9; KCl, 10.0; $CaHPO_4 \cdot 2H_2O$, 46.0; $MgSO_4$, 6.8; $CaSO_4 \cdot 2H_2O$, 20.0; $CaCO_3$, 2.0; $Fe(C_6H_5O_7)_2 \cdot 6H_2O$, 2.0; KI, 0.06; $MnSO_4 \cdot 4H_2O$, 0.1; $ZnCl_2$, 0.02; $CuSO_4 \cdot 5H_2O$, 0.11; $CoCl_2$, 0.01.
[3] Vitamins per sheep per day: Vitamin A—3000 U.S.P. units.
Vitamin D— 300 U.S.P. units.
α-tocopherol— 5 mg.

Experiment II employed eight two-day old lambs, one two-week old lamb and seven two-day old goats. The synthetic milk basal diet (table 2) was designed after those of Clark (1929) and Wiese *et al.* (1947) employing the modifications of Sewell (1953). Several lambs and kids received the fat-free basal diet while various levels of lard and linoleic acid replaced part of the glucose in the diets of others.

The lard contained 10.2, 0.7, and 0.3 percent linoleic, linolenic, and arachidonic acids, respectively. It was homogenized in two parts of water with soya lecithin acting as an emulsifying agent and stored at 5°C. until used. Fresh milk was mixed every three to four days. The fat soluble vitamins were dissolved in 95 percent alcohol and added

[2] All cultures employed in this study were obtained from fistulated cows and contributed by Dr. R. H. Wasserman, Animal Husbandry Department, Cornell University, and Dr. L. S. Gall, National Dairy Research Laboratories, Inc., Oakdale, L. I.

to the milk at the time of feeding. The lambs and kids were fed five and four times a day, respectively, with nipple bottles. The milk was warmed before feeding and only as much was given as the animals would accept without developing severe digestive upsets. Shredded cellophane and a dry mixture of 15 percent alpha protein, 14 percent glucose, 65 percent potato starch and 7 percent minerals were supplied

TABLE 2. FAT-FREE SYNTHETIC MILK BASAL DIET USED IN EXPERIMENT II

Ingredient	gm./kg. Diet	Vitamin	Mg./kg. Diet
H_2O	875.4	Thiamine	0.65
$Ca(OH)_2$	1.0	Riboflavin	0.65
Alpha protein [1]	40.0	Niacin	2.50
Methionine	0.66	Choline chloride	260.00
Cerelose	74.0	Para-amino-benzoic acid	2.60
KOH	0.959	Folic acid	0.052
NaOH	0.928	Pyridoxine	0.65
$CaCl_2$	1.565	Ca Pantothenate	1.30
HCl	0.101	B_{12}	0.0074
$CaCO_3$	0.140	Alpha tocopherol	5.0
$FeSO_4.7H_2O$	0.050	Vitamin A	5000 I.U.
$CuSO_4.5H_2O$	0.004	Calciferol (D_2)	400 I.U.
$CoCl_2.6H_2O$	0.0014		
$MnSO_4.4H_2O$	0.0034		
$ZnSO_4.7H_2O$	0.0031		
KI	0.0003		
MgO	0.298	Aureomycin HCl	10 mg.
KH_2PO_4	2.873		
Citric acid	1.998		

[1] The alpha protein was treated to remove sulfites by autoclaving at 10 pounds for 10 minutes and then washing three times with an excess of water. It was then dried at 100°C. and finely ground in a Wiley Mill. The fat was removed by boiling the alpha protein for one hour in 95% alcohol and extracting in a continuous type extractor for 24 hours with the same solvent.

ad libitum beginning at two weeks of age. All animals were weighed weekly and plasma lipid determinations were taken on the lambs at three to seven weeks of age. Animals that died were autopsied and histological examinations made on sections of the brain, kidney, liver, and heart.

Results and Discussion

Experiment I

At no time during Experiment I did the weanling lambs exhibit any symptoms typical of an essential fatty acid deficiency. However, whenever the feed intake approached optimum for calories, the lambs showed some bloating and went "off feed" for several days. As a result, all

lambs lost rather than gained weight during the 240 days of the experiment with average weight losses of 3.5 and 4.0 kg. for those receiving fat and fat-free diets, respectively. In view of the fact that the lambs were not growing, and therefore probably required little or no essential fatty acids for growth and repair of body tissues, it is possible that tissue storage of lipids was sufficient to prevent a fat deficiency.

Eight blood samples were obtained from each sheep from the 28th to 227th day of the experiment. Mean plasma values for sheep receiv-

TABLE 3. LIPIDS FOUND IN THE RUMEN CONTENTS OF LAMBS IN EXPERIMENT I[1]

Sheep No.	Days on Trial	Total Lipids	Linolenic Acid	Linoleic Acid
			(mg./100 ml.)	
		Corn Oil Diet		
3	124	155	1.6	82.5
3	131	238	4.1	114.6
3	146	170	0.0	160.5
3	164	217	2.1	100.8
		Fat-Free Diet		
2	124	65	3.3	30.6
4	124	75	3.1	6.2
2	131	40	3.8	9.6
4	131	38	2.8	4.8
4	146	25	0.0	2.5
2	164	43	1.2	3.2
4	164	88	1.0	1.8

[1] No arachidonic acid was detected in the rumen contents of any sheep.
[2] A nitrogen equivalent of urea replaced the alpha-protein on the 112th day.

ing corn oil for this period were: total lipids, 138.5 $\pm$ 51.6[3]; arachidonate, 6.2$\pm$2.2; linolenate, 0.15$\pm$0.39; and linoleate, 17.4$\pm$6.9 mg. per 100 ml. In comparison, mean plasma values for the fat-free group were: total lipids, 102.5 $\pm$ 30.1; arachidonate, 4.3 $\pm$ 1.9; linolenate, 0.93 $\pm$ 1.6 and linoleate, 7.9 $\pm$ 2.9 mg. per 100 ml. Although there was no decline in the plasma total lipid or unsaturated fatty acid levels of the sheep on either diet, the lambs receiving corn oil maintained significantly higher plasma total lipids ($P<0.05$)[4], and linoleic acid ($P<0.01$) levels throughout the experiment. There was no significant difference between the linolenic and arachidonic acid levels of the sheep on the two diets.

Table 3 shows the lipid analysis of samples of rumen contents drawn

[3] Standard deviation.
[4] Means compared by a "t" test.

from several sheep from the 124th to 164th day of the experiment following the incorporation of urea in the diet on the 112th day. Arachidonic acid was not detected in the rumen contents of any sheep and only traces of linolenic and linoleic acids were found in the rumen contents of the sheep on the fat-free diet. As expected, the rumen ingesta of the controls receiving 1.5 percent corn oil (of which 56 percent was linoleic and 0.91 percent was linolenic acid) contained larger quantities of linoleic acid than ingesta from sheep on the fat-free diet.

TABLE 4. LIPID CONTENT OF ISOLATED RUMEN BACTERIA

Bacterium	Medium [1] No.	Hours [2] Medium was Extracted	Yield of [3] Bacteria Per Liter of Medium (mg.)	Lipid Content of Bacteria Grown in 1 Liter of Medium		
				Total Lipids (mg.)	Linolenic Acid (mg.)	Linoleic Acid (mg.)
Anaerobe 114	1	0	790	24.6	0.7	2.2
Anaerobe 114	1	24	626	20.0	0.4	1.2
Anearobe 114	1	48	678	26.3	0.0	0.1
Facultative	1	48	585	18.5	0.0	0.0
Anaerobe RO-C8	2	120	...	26.2	0.1	0.6
Anaerobe 118.2	3	fat-free	566	36.7	0.0	0.0
Anaerobe 56.8	3	fat-free	...	10.1	0.0	0.0

[1] Medium No. 1 consisted of bacto-peptone, glucose, yeast extract and inorganic buffers.
Medium No. 2 consisted of bacto-peptone, glucose, yeast extract, beef extract and inorganic buffers.
Medium No. 3 was composed entirely of pure amino acids, purines, vitamins, glucose, trace minerals, and inorganic buffers.
[2] Several of the media were extracted with petroleum ether (60–70) in a continuous type extractor before they were used for culturing bacteria.
[3] Dry weight.

Similar results were obtained with *in vitro* studies with pure rumen bacterial cultures. Several bacteria (table 4), when grown on a peptone-yeast extract, or a peptone-tryptone, yeast and beef extract type medium, contained small amounts of linoleic and linolenic acid and synthesized large quantities of other non-volatile lipids. However, since the media contained yeast or beef extract (required to supply vitamins and unidentified factors), they were not completely fat-free and there was a possibility that the organisms were simply concentrating the lipids found in the media. This assumption was borne out by the fact that when the media were extracted with petroleum ether, the quantities of linoleic and linolenic acids incorporated by the bacteria decreased in proportion to the length of time the media were subjected to extraction.

Two rumen bacteria were found which would grow on a completely fat-free synthetic medium. Table 4 shows that though these bacteria synthesized appreciable quantities of lipids, they produced no detectable amounts of the essential fatty acids. The fact that these bacteria did not synthesize linolenic or linoleic acid does not necessarily mean that

TABLE 5. SUMMARY OF DIETS, WEIGHTS, AND FEED CONSUMPTION FOR LAMBS AND GOATS IN EXPERIMENT II

Animal No.	Days on Trial	Fat per kg. of Diet [1] (gm.)	Av. Daily Milk Intake (gm.)	Av. Daily Cello-phane Intake (gm.)	Av. Daily Dry Mix Intake (gm.)	Initial wt. (kg.)	Av. Daily Gain (gm.)
Lambs							
1	77	25	822	20	54	2.5	96
2	74	25	1157	24	55	3.4	123
3	68	25	1191	22	56	3.8	160
4	73	25	1149	22	47	3.4	114
5	35 [a]	0	561	0	9	3.0	29
6	48 [a]	0	800	0	6	3.4	27
7	20 [a]	0	533	0	10	2.9	1
8	48 [a]	0	1002	0	4	5.2	37
9	72 [2]	0	878	40	61	4.2	69
Goats							
1	13 [a]	0.5	741	0	0	4.1	8
2	115	2.5	836	5	15	2.4	28
3	34 [3]	2.5	790	0	0	2.6	62
4	147	3.6 [4]	877	52	67	3.8	52
5	90	5.5 [4]	810	19	14	2.4	61
6	23 [a]	0	577	0	0	3.0	26
7	9 [a]	0	443	0	0	2.1	0

[a] Animal died.
[1] Quantity of lard-lecithin mixture that replaced an equal amount of cerelose.
[2] Lamb 9 was with its mother for 2 weeks before receiving the fat-free diet.
[3] Goat 3 died from broncho pneumonia.
[4] Linoleic acid was fed instead of lard. The diet of goats 4 and 5 contained 6.6 and 10.0 gm., respectively, per kg. of a preparation containing 55% linoleic acid.

other rumen bacteria not studied may not possess these capabilities. However, these data coupled with the *in vivo* studies using weanling lambs suggest that the synthesis of the essential fatty acids by rumen bacteria from fat-free media is probably extremely limited.

Experiment II

The lambs in Experiment II which received 25 gm. of fat per kg. of milk survived past 10 weeks of age and as shown in table 5, made

average gains of 119 gm. per lamb per day. On the other hand, the lambs receiving the fat-deficient diet showed slight weight gains for 3 to 7 weeks and then suddenly displayed a peculiar syndrome. At first, upon rising to be fed, the front legs of the lamb would collapse and it would fall over forward. The lamb would regain its feet and perhaps stand up quite easily, but this performance would be repeated a day or so later and it would become progressively weaker and finally die. Affected lambs appeared very dull and listless and during the later stages there was a retention of large amounts of fluid which could be felt upon palpation of the abdomen. Some lambs showed twitching of

TABLE 6. PLASMA LIPID ANALYSIS OF LAMBS IN EXPERIMENT II

Lamb No.	Age (Days)	Total Lipids	(Mg. per 100 ml.) Arachidonic Acid	Linolenic Acid	Linoleic Acid
			Lard Diet		
1	30	210	6.9	3.4	50.7
2	27	227	10.7	0.2	45.9
3	38	225	11.2	0.0	13.7
4	36	307	8.9	0.1	48.7
Av.	33	242	9.4	0.9	39.8
			Fat-Free Diet		
5	30	215	3.8	3.9	11.2
6	27	118	1.5	5.5	8.0
8	35	93	3.2	0.7	5.4
9	48	135	4.8	0.0	4.1
Av.	35	140	3.3	2.5	7.2

the legs or entire bodies and all lambs displayed a continual chewing movement of the jaws. Thiamine injections had no effect on any of these symptoms. Lamb 9, which was with its mother for 2 weeks before receiving the fat-free diet, survived without showing any of the above symptoms.

Table 6 shows that the lambs receiving lard had higher plasma total lipids, arachidonic and linoleic acid levels than the fat-deficient lambs. The differences between means when compared by a "t" test were significant at the 5, 1 and 2 percent probability levels, respectively. However, as in the previous experiment, there was a tendency for the linolenic acid levels to be slightly higher, but not significantly so, in the plasma of the animals on the fat-free diet. Higher than normal levels of trienoic acid in the tissues of fat-deficient rats have been observed previously by various workers (Nunn and MacLean, 1938; Riechehoff

et al., 1948). It was found to consist largely of dihydroarachidonic acid and was postulated (Kummerow *et al.*, 1951) to represent a vain effort of the body to synthesize the essential arachidonic acid.

Young goats receiving a fat-free diet showed identical symptoms to those displayed by lambs except that they were affected somewhat earlier. Signs of leg weakness, staggering, difficulty in rising and chewing movements of the jaws appeared within 7 to 21 days. The kids soon became too weak to rise and died. Levels of 2.5 gm. of lard or 3.6 and 5.5 gm. of linoleic acid per kg. of milk were found to be sufficient to prevent the occurrence of these symptoms while a level of 0.5 gm. of lard had no apparent effect.

Summary

Weanling lambs were fed a fat-free diet for seven months without showing any skin lesions or other symptoms typical of a fat deficiency. Although analysis of rumen contents from these sheep indicated the presence of traces of linoleic and linolenic acids, the concentration of these acids declined as the experiment progressed. No arachidonic acid was detected in the rumen contents of sheep receiving fat-free or corn oil diets.

Several bacteria were isolated from the rumen of a cow consuming a natural diet and grown on fat-free media. None of these bacteria were found to synthesize any of the "essential fatty acids".

A second experiment was undertaken to determine if two-day old lambs and goats require a dietary source of fat. Lambs which received a fat-free synthetic milk became weak and died within three to seven weeks while controls were raised successfully on the same milk with 2 percent added lard. Kids receiving fat-free diets showed symptoms identical to those displayed by lambs but died within one to three weeks. Other kids survived on a milk containing as little as 0.25 percent lard or 0.36 percent linoleic acid but not on a milk containing 0.05 percent lard.

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THE EFFECT OF PHLEBOTOMY VERSUS STOMACH WORM, *HAEMONCHUS CONTORTUS,* INFECTION ON THE GROWTH AND CERTAIN BLOOD CONSTITUENTS OF LAMBS [1]

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VARIOUS postulations have been made as to the cause of the deleterious effect which the stomach worm *(Haemonchus contortus)* has upon the host animal. Lambs heavily infected with *Haemonchus contortus* develop a severe anemia. This implies a host-parasite relationship capable of producing these symptoms. The findings of Veglia (1915), Fourie (1932), Martin and Clunies Ross (1934), and Andrews (1942) supported the contention that the effects of infection with *Haemonchus contortus* were due to a continual loss of blood. The blood-sucking action of the parasite was confirmed by Boughten and Hardy (1935). Taylor (1929) and Schwartz (1921), however, postulated that parasitic worms secrete toxic substances which are absorbed by the host, producing the resulting pathological condition. Stewart (1933) has been the leading exponent of the theory that the injury to the host by nematode infections is due to an impairment of digestion.

The present experiment was conducted to obtain further information on the possible relationship between parasite and host, and the effect of certain hemopoietic dietary factors on the resistance of lambs to stomach worm infection. Earlier work on this project (Weir *et al.,* 1948; Badr, 1949) indicated that supplementation of the ration with certain minerals resulted in an increased resistance to haemonchosis.

Experimental Procedure

Parasite-free lambs were produced from four lots of ewes fed the rations shown in table 1. The lambs were creep-fed rations corresponding to those of their dams with the exception of oat straw. When the lambs were approximately 3½ months of age, two lambs in each lot were each artificially infected with 40,000 stomach worm larvae and

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paired with lambs of similar weight and age. Twins were used with the exception of one pair in lot IV. The noninfected lamb of each

TABLE 1. RATIONS FED EXPERIMENTAL EWES

Lot No.	Pounds per Day Before Lambing	After Lambing
I—Basal		
Alfalfa hay	1.9	2.0
Oat straw	2.0	2.0
Gr. corn	1.0	1.7
Iodized salt	Free choice	Free choice
Nutritive ratio	1:8	1:8
II—Basal+minerals		
Alfalfa hay	2.03	2.25
Oat straw	2.14	2.25
Gr. corn with 1% bone meal	1.07	1.92
Trace mineralized salt [1]	Free choice	Free choice
Nutritive ratio	1:8	1:8
III—Basal+protein		
Alfalfa hay	4.3	4.0
Gr. corn	0.4	1.25
Soybean oil meal	0.22	0.25
Iodized salt	Free choice	Free choice
Nutritive ratio	1:4	1:4
VI—Basal+protein+minerals		
Alfalfa hay	4.81	4.42
Gr. corn with 1% bone meal	0.45	1.30
Soybean oil meal	0.25	0.29
Trace mineralized salt [1]	Free choice	Free choice
Nutritive ratio	1:4	1:4

[1] Trace mineralized salt—The following added to 100 lb. salt:

10.25 gm. KI
102.50 gm. Na_2SO_4
205.00 gm. $Na_2S_2O_3$
5.00 gm. $CoCO_3$
50.25 gm. $CuSO_4$
50.25 gm. Fe_2O_3
100.50 gm. $MnSO_4 \cdot H_2O$
361.80 gm. $FeSO_4$

pair was used to determine both the extent and the effect of hemorrhage produced in the abomasum of the infected lamb. The amount of blood lost through parasitic hemorrhage was approximated by removing daily a volume of blood from the noninfected lamb sufficient to maintain the hemoglobin level comparable to that of its infected mate. The control

in each lot consisted of a single lamb which received neither of the two treatments mentioned previously. Data on fecal egg counts, hemoglobin levels, growth, and B-vitamin levels in the blood were collected. Hemoglobin was determined by the oxyhemoglobin method. Fecal egg counts were determined by the method of Stoll (1930). Niacin was determined by the microbiological method of U. S. Pharmacopoeia XIII (1947). Vitamin B_6 was determined microbiologically by the method of Lawrence *et al.* (1943).

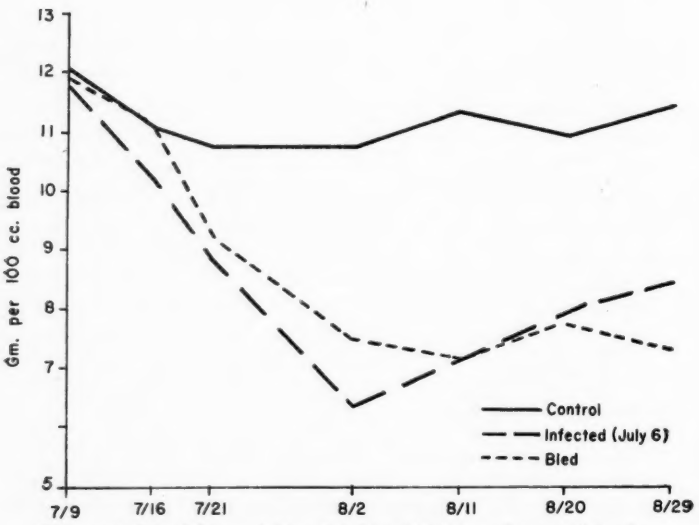

Figure 1. Blood hemoglobin of infected, bled, and control lambs.

Results and Discussion

Within each lot, no significant difference was observed between the infected and phlebotomized lambs. The data from the lots are therefore combined and presented as such in the interpretation of the results.

Ten days after the administration of the stomach worm larvae, a drop in the hemoglobin of the infected lambs was observed. Simultaneously the removal of blood from the jugular vein of the noninfected lambs, with the exception of the control animals, was begun. Fifty cc. were removed daily from each lamb for 5 days. The amount was then increased to 100 cc. per day. The average blood hemoglobin levels,

in figure 1, show that despite the removal of this large volume of blood, the decline in the blood hemoglobin of the phlebotomized lambs was insufficient to keep pace with the anemia which developed as a result of the infection. Accordingly, the volume was increased to 200 cc. per day, and the removal of that amount was continued for the remainder of the experiment.

The lowest hemoglobin levels among the infected lambs occurred, in most cases, about 1 month following infection (figure 1). On July 9, the average blood hemoglobin of the infected lambs was 11.78 gm. per 100 ml. of blood. By August 2, the concentration had decreased to 6.35 and two lambs died from haemonchosis infection. The other infected lambs survived, but the anemia was severe. The anemia pattern was similar for all of the infected lambs. After a period of 4 to 5 weeks following infection, the decline in blood hemoglobin stopped and a recovery phase ensued, characterized by a gradual regression of the anemia. During the period of recovery, beginning August 2, an average increase of 2.06 mg. percent occurred in the blood hemoglobin concentration of the infected lambs until the termination of the experiment on August 29.

As was the case with the infected lambs, the decrease in the hemoglobin levels of the phlebotomized lambs was followed by a marked diminution of the rate of decline after which the hemoglobin levels remained relatively constant. The point at which the leveling off occurred corresponded closely to a similar arrest of the anemia in the infected animals. This would tend to indicate that the ability of lambs to recover from stomach worm infection may be due, at least in part, to an increased hemopoietic response. The average blood hemoglobin of the phlebotomized lambs decreased from 11.92 mg. percent to 7.48 mg. percent during the period from July 9 to August 2. The level remained relatively constant so that the concentration had been maintained at 7.22 mg. percent after 45 days of periodic bleeding.

During the 45-day period from July 16 to August 29, an average of 6,687.5 cc. of blood was removed from each of the lambs being bled. Assuming that blood constitutes 8 percent of the body weight of the lamb, the amount of blood removed by artificial hemorrhage was 3.2 times the initial blood volume. If one may asume that a similar amount of blood was withdrawn from the infected lambs by their respective parasitic infections, these data provide a measure of the severe strain imposed on the nutritive supply of the lamb by heavy stomach worm infection.

It would seem plausible that the withdrawal of such a volume of blood would produce a simultaneous decrease in the blood level of certain nutrients. Previous work by Badr (1949) indicated that the concentrations of certain of the B-complex vitamins in the blood were lowered during severe haemonchosis. Analyses were conducted to determine if the decrease in the B-vitamin concentration of the blood can be explained on the basis of blood loss, as induced by the blood sucking action of stomach worms.

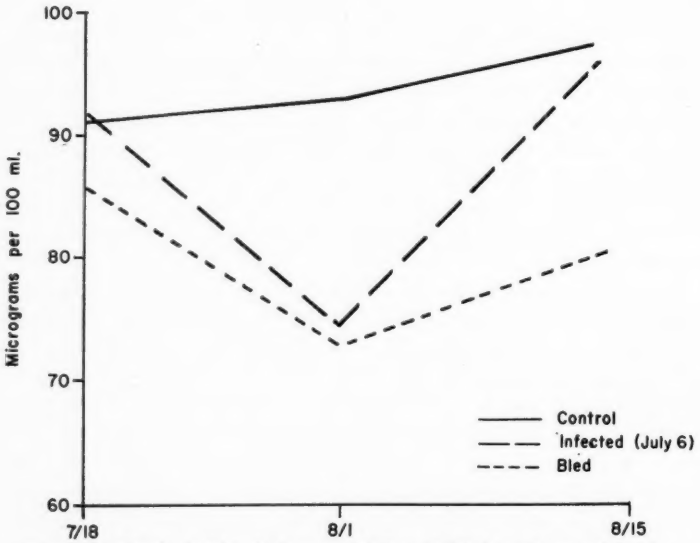

Figure 2. Niacin in blood plasma of infected, bled, and control lambs.

The effect of *Haemonchus contortus* infection on blood plasma niacin is shown in figure 2. The infection caused a decrease in the plasma niacin of all infected lambs. The concentration decreased from 91.7 γ to 75.3 γ per 100 ml. of plasma during the period from July 18 to August 1. From August 1 to August 15 the average plasma niacin of the infected animals had increased to 97.2 γ. The increase coincided with the recovery of the lambs from the infection.

Similarly, there was a reduction in the vitamin B_6 concentration of the blood plasma of lambs infected with *Haemonchus contortus*. Figure

3 illustrates the rapidity with which the infection lowered the B_6 blood level. Within 2 weeks, from July 18 to August 1, the B_6 concentration decreased from 7.7 γ to 6.2 γ per 100 ml. The lower level was observed when fecal egg counts were at the highest peak. Following the infection peak, the average plasma B_6 of infected lambs increased, reaching a concentration of 8.2 γ by August 15.

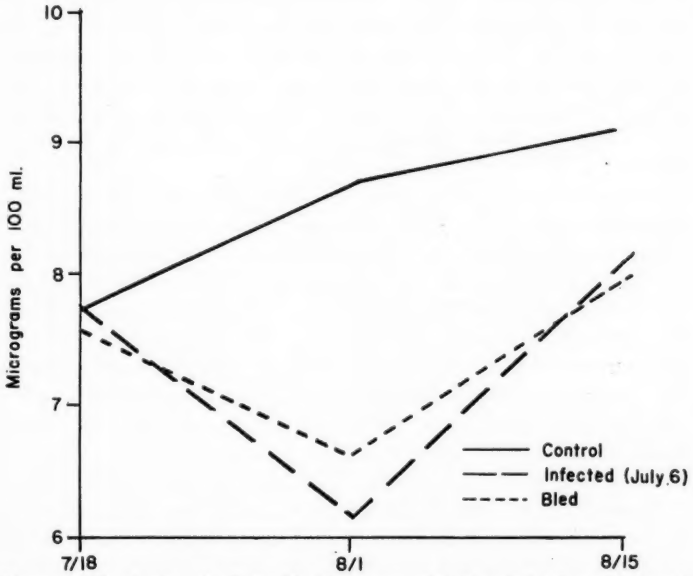

Figure 3. Total vitamin B_6 in blood plasma of infected, bled, and control lambs.

Figures 2 and 3 further show that the effect of artificial hemorrhage upon the plasma niacin and vitamin B_6 levels was similar to the effect produced by the actual stomach worm infection. From July 18 to August 1, daily blood withdrawal decreased the average plasma niacin level from 86.8 γ to 73.6 γ per 100 ml. and the average plasma B_6 from 7.6 γ to 6.8 γ per 100 ml. Another fact which enhanced the similarity between the blood picture of the infected and phlebotomized lambs was the increase which occurred in the plasma vitamin levels of the latter during the later phase of the experiment. On August 15 the average con-

centration of niacin and B_6 in the plasma of phlebotomized lambs was 80.3 γ and 7.9 γ respectively per 100 ml. of plasma. The increase corresponded closely to the rise of the vitamins in the plasma of the parasitized lambs during the same period.

Both phlebotomy and stomach worm infection adversely affected the weight gains of the lambs. Control lambs gained an average of 0.63 pound per lamb daily from July 8 to August 26. In comparison the average daily gain of infected and phlebotomized lambs was 0.40 and 0.43 pound respectively. The most pronounced effect upon growth was observed during the third, fourth, and fifth weeks of the infection. Following the fifth week, an increased rate of gain was observed in most cases. The increased growth response followed the regression of the anemia and the rise in the niacin and vitamin B_6 level of the blood plasma.

Mineral supplementation, with or without protein supplementation, appeared to give the greatest resistance against the development of anemia. During the first 33-day period there was a reduction of 50.7 percent in the hemoglobin of the infected lambs which received only the basal ration (see figure 4). The protein supplemented lambs in lot III had a less severe reduction, 40.2 percent. The reduction was 32.1 and 34.3 percent in lots II and IV respectively where the minerals were fed. It was also observed that there was a close correlation between the infection peak, as measured by fecal egg counts, and the most severe stage of anemia in the infected lambs.

The growth response of infected lambs was increased by the addition of minerals to the ration. The average daily gain was 0.44 pound for lambs which received the basal ration plus minerals and 0.42 pound for lambs which received protein in addition to minerals. The lambs which received protein as the only supplement to the basal ration, gained an average of only 0.25 pound per lamb daily. The death of one of the infected lambs in the basal group resulted in an actual weight loss in that lot of 0.23 pound per day.

The noninfected control lambs maintained normal blood hemoglobin levels and made excellent weight gains. The rations semed to be of equal value in supporting the growth of young lambs, providing the lambs were not exposed to the stress of heavy stomach worm infection.

Summary

An experiment was conducted to study the host-parasite relationship in lambs infected with the stomach worm, *Haemonchus contortus*, and to determine the effect of certain hemopoietic dietary factors on the re-

sistance of lambs to stomach worm infection. The blood hemoglobin levels of lambs were depressed in all cases by the parasite infection. Other blood constituents—plasma niacin and vitamin B_6—were also

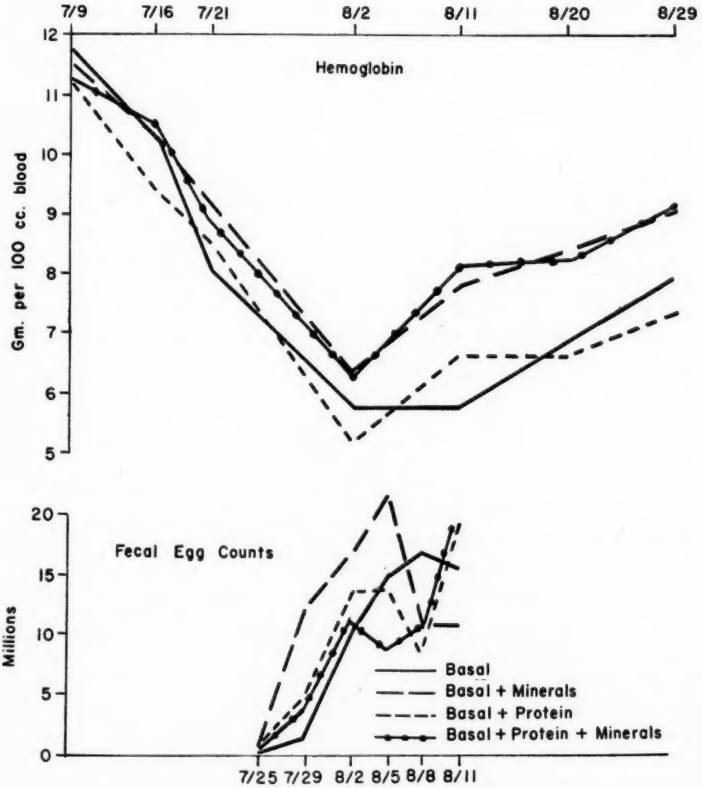

Figure 4. The effect of ration on blood hemoglobin and fecal egg counts of lambs infected with 40,000 larvae July 6.

adversely affected. Growth was retarded. Phlebotomy alone produced similar effects. The anemia was less severe and weight gains were better in the case of lambs which received trace minerals plus steamed bone meal. Increasing the protein, with or without minerals, appeared to be of little value in increasing the resistance of lambs to stomach worm infection.

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COMPARISON OF THE DIGESTIBILITY OF CERTAIN PASTURE FORAGES IN THE FRESH AND DRIED STATES

W. J. MILLER, R. K. WAUGH and G. MATRONE

North Carolina Agricultural Experiment Station [1]

IN pasture studies it is desirable to know the digestibility of the forage in the sward, but, as the digestibility of pasture plants cannot be determined easily under natural grazing conditions, research workers often have harvested the forage and fed it to animals. This requires either soiling or preserving the forage. Ordinarily, the latter practice is more convenient and subject to greater experimental control than is soiling because it permits an entire digestion trial to be conducted on a uniform lot of forage. However, before a method of preservation is used it would be beneficial to know whether there are changes in digestibility caused by the preserving process. Therefore, an experiment was designed to study the effects of drying on the digestibility of three important pasture plants.

In an experiment employing cows, Newlander and Jones (1932) found that digestibilities of the dry matter in artificially dried and fresh green grass were not significantly different. The protein of the fresh forage was more digestible than that in the dried forage, while the reverse was true with the ether extract. In 1948, Zimmerman found the protein in dried grass less digestible than that in green grass. Wagner (1921) observed a similar decrease in the digestibility of the protein of leaves from fodder beets, sweet fodder beets, and sugar beets following drying. He also found that the quantity of the protein in these materials was not measurably affected by drying at 60° or at 105–110° C., but that the protein was less digestible in the leaves dried at the higher temperatures.

Inasmuch as Ladino clover, tall fescue, and orchard grass are very important to this area, they were chosen as the pasture forages to be studied. The lignin fraction was included in the study because of its relationship to forage quality, its use in determining digestibility by ratio (Ellis *et al.*, 1946), and because there was only limited data on it in this type of forage. Various workers have obtained fairly reliable digestion coefficients with the lignin-ratio technique (Ellis

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[1] Department of Animal Industry, Raleigh.

et al., 1946; Forbes, E. B., *et al.*, 1946; Forbes, R. M., and Garrigus, 1948, 1950 and 1950b; Swift *et al.*, 1947; and Kane *et al.*, 1949). From chemical studies, Sowden and Delong (1949) and Pazur and Delong (1948) have indicated that results obtained by the lignin-ratio method may be inaccurate when applied to immature pasture forages.

Experimental

The study consisted of digestion trials with rabbits using three forage species and two treatments with four replications. Two replications were carried out in August and two in September of 1949.

TABLE 1. CHEMICAL COMPOSITION OF FEED USED IN DIGESTION TRIALS

(Dry Basis)

Forage Species	Replication	Ether Extract	Protein	Crude Fiber	Ash	N.F.E.	Lignin
		(%)	(%)	(%)	(%)	(%)	(%)
Ladino clover	1, 2	5.1	30.6	14.7	9.9	39.8	5.2
Ladino clover	3, 4	5.3	31.3	13.6	10.1	39.7	4.5
Tall Fescue	1, 2	6.1	23.9	23.8	9.7	36.4	4.6
Tall fescue	3, 4	5.7	25.2	24.8	10.4	33.9	4.9
Orchard grass	1, 2	7.0	26.4	24.2	9.8	32.6	5.3
Orchard grass	3, 3	7.1	27.0	23.9	9.5	32.6	5.1

The species-treatment combinations within a replication were as follows: (a) Ladino clover, green; (b) Ladino clover, dry; (c) tall fescue, green; (d) tall fescue, dry; (e) orchard grass, green; and (f) orchard grass, dry. In order to simulate practical conditions, the grasses were grown in association with Ladino clover and then separated into pure species. All the forages were harvested at what was considered to be an ideal grazing stage.

The animals used were male, black and white Dutch rabbits which were 17 weeks of age, with body weights ranging from 1110 to 1585 grams. Rabbits within a replication were assigned to cages and diets at random and were fed at the same dry matter level because of work by Hellberg (1949) which indicates that the level of feeding affects the apparent digestibility of dry matter, protein, fat, nitrogen-free extracts, crude fiber, and ash. Those in replication 1 received 30 grams of dry matter daily, those in replication 2 received 40 grams daily, and those in replications 3 and 4 were fed 50 grams daily. Quick determinations of dry matter were made with a portable electric

[2] Manufactured by Harry Dietert Co., Detroit, Michigan.

drier.[2] It was estimated that 30–35 grams of dry matter in the clover, or 50–60 grams daily in one of the grasses was required to maintain a rabbit at a constant weight.

Fresh succulent forage of each species was harvested every two days. One portion of each sample was held in a refrigerator at 38° C. until fed and the other was dried in a forced air oven at 55–60° C. Fecal material was collected daily, sprinkled with ethyl alcohol and dried at 55–60° C. in the same oven. The dried fecal and forage samples were analyzed for dry matter, ether extract, nitrogen, ash, and crude fiber by A.O.A.C. (1946) methods; and for lignin by the 72 percent H_2SO_4 method (Ellis *et al.*, 1946). Crude protein, nitrogen-free extract and total digestible nutrients (TDN) were calculated. The urine was preserved with formaldehyde and toluene and refrigerated until analyzed for nitrogen. A nitrogen balance determination was made on each rabbit.

All the data were analyzed by the analysis of variance technique (Snedecor, 1946).

Results and Discussion

Drying depressed the digestibility of the protein ($P=.01$) and of the lignin ($P=.05$) in all three forage species (table 2). The lowered digestibility of the protein is in agreement with the work of Zimmerman (1948), Newlander and Jones (1932), and Wagner (1921). Although the reason for the decrease in digestibility of protein is not known, it is possible that on heating the reducing sugars in the forage may have reacted with the protein and thereby lowered its nutritional value (Nutrition Foundation, Inc., 1952).

The crude fiber of the dried grasses was more digestible than that of the green ones (table 2) ($P=.05$) but this difference did not appear in the clover. Drying decreased the digestibility of the nitrogen-free extract of the clover 3.1 percent, whereas it increased the digestibility of that of the fescue and orchard grass 1.0 and 5.7 percent, respectively. This interaction was statistically significant. A possible explanation of the foregoing results is that drying may have influenced digestibility indirectly by affecting the rate of passage of the poorly digested grass in the digestion tract in a different manner than that of the highly digested clover. There were no differences ($P>.05$) in dry matter and ether extract digestibility, total digestible nutrient or nitrogen balances associated with drying.

All of the nutrients studied were more digestible in the Ladino clover than in either of the grasses (table 2). However, the differences

TABLE 2. AVERAGE DIGESTIBILITY COEFFICIENTS OF DRIED AND GREEN FORAGES

Treatment	Forage	Dry Matter	TDN	Ether Extract	Protein	Crude Fiber	N.F.E.	Lignin	Nitrogen Balance[1]
Dry	Ladino clover	78.5	75.4	54.7	83.6	64.4	85.7	21.7	3.3
	Tall fescue	47.8	47.8	51.9	81.1	26.2	41.4	2.8	1.4
	Orchard grass	51.3	51.2	41.9	75.0	37.3	47.7	2.3	1.5
Av. (dry)		59.2	58.1	49.5	79.9	42.7	58.3	8.9	2.1
Green	Ladino clover	81.3	77.7	54.4	86.8	65.2	88.8	26.4	3.4
	Tall fescue	47.5	47.6	53.3	84.4	22.8	40.4	6.0	1.5
	Orchard grass	48.2	48.4	43.4	79.5	27.6	42.0	9.1	1.7
Av. (Green)		59.0	57.9	50.4	83.6	38.5	57.1	13.9	2.2

[1] Nitrogen balance per rabbit per 7-day period (grams).

in the digestibility of the ether extract between the clover and the fescue were small (table 2) but in both it was appreciably (P=.01) more digestible than that in the orchard grass. The protein of the fescue was more digestible than that of the orchard grass (table 2).

The nitrogen balances were higher (table 2) (P=.05) for the rabbits fed the clover than for those which received the grasses. The higher energy content of the clover ration probably influenced the nitrogen balances.

The crude fiber of the orchard grass was 7.9 percent (P=.05) more digestible than that of the fescue. The digestibility of the dry matter, nitrogen-free extract and lignin and the total digestible nutrients were not significantly different for the two grasses.

The average digestibility of the lignin in the Ladino clover was 24.1 percent. The reason for the highly significant digestibility of lignin in the Ladino clover of this experiment is not known. A subsequent investigation employing Ladino clover did not confirm these results (Smart, 1950). It is possible that the season of the year and stage of maturity markedly affect the lignin in Ladino clover. The results of this experiment when considered along with the findings of Sowden *et al.* (1949) indicate that further work on the digestibility of lignin in immature clovers would be desirable.

Summary

Artificial drying (60° C.) decreased the digestibility of the protein (P=.01) and the lignin (P=.05) of Ladino clover, tall fescue, and orchard grass. The crude fiber of the orchard grass and the fescue was more digestible following drying. Drying increased the digestibility of the nitrogen-free extract of the fescue, while decreasing its digestibility in the clover. The digestibility of the ether extract and the dry matter were not appreciably affected by drying. In the same experiment, rabbits digested all the nutrients of Ladino clover to a greater extent than they did those of either tall fescue or orchard grass. The ether extract and the protein of the fescue were more digestible than those of the orchard, whereas the crude fiber was more digestible in the orchard grass. Digestibility of the dry matter, nitrogen-free extracts, and lignin and the total digestible nutrients were not significantly different in the grasses. The lignin of the clover was 24.1 percent digestible.

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RECORD OF THE PROCEEDINGS OF THE FORTY-FIFTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The forty-fifth annual meeting of the American Society of Animal Production was held in the Hotel Sherman in Chicago on November 27 and 28, 1953 and a dinner for the honor guest was held at the Stockyard Inn on November 29. Abstracts of most of the papers presented were published in the November, 1953 issue of the JOURNAL OF ANIMAL SCIENCE, Volume 12, pages 892–957.

PRESIDENT'S REMARKS AT OPENING SESSION

M. L. BAKER

President, American Society of Animal Production

It is encouraging that we have such a large attendance at this, the forty-fifth annual meeting of the Society. The attendance reflects the condition of the Society. At the business meeting Saturday afternoon the Secretary and the Editor will present their formal reports.

I shall say only that the year has been one of growth and progress due primarily to the effective work of the Secretary, the Editor, the Committees of the Society and the support of its membership.

North America has changed greatly since 1862 when the first Land Grant Act became a law; since 1887 when the first federal funds were authorized for the support of organized agricultural research in the state experiment stations; and since 1914 when the cooperative agricultural extension service was established.

The Land Grant Institutions have played a decisive and vital role in the development of this country. In this, animal husbandry has played an important role.

Animal husbandry has come a long way since 1898 when Professor Henry published the first edition of "Feeds and Feeding" or since 1908 when the Society was organized. This is not a very long time. It is within the lifetime of a good many of us. I have known almost one-half of the charter members of this Society. Generally, they were men of vision and purpose who builded well.

It is a great inspiration to see the alert, well-trained young men who

come into the Society each year until our membership now stands at about 1300. I am sure that they will do for their day as well as the 33 men who launched this Society in 1908 did for theirs.

It is only natural that the Society has changed greatly in many ways in the past 45 years. On the premise that the proper study of mankind is man, it seems proper that groups should look at themselves; that they should consider the "rock from which they are hewn"; that they should attempt to place themselves in proper perspective as far as the present is concerned; and that they should look at the pitfalls and opportunities of the future.

I have asked three of my good friends, men who have been and are leaders in the field of animal husbandry, and men who have served the Society well, to help us do these things. These men, Colonel E. N. Wentworth, Dr. T. C. Byerly and Dean and Director A. D. Weber need no introduction to this group.

A SUMMARY OF THE MINUTES OF THE FORTY-FIFTH BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

J. I. MILLER, *Secretary*
Cornell University

The meeting was called to order in the Louis XVI Room of Hotel Sherman, Chicago, on November 28, at 2:30 p.m. by President Baker. The minutes of the 1952 business meeting were not read but were approved as published in the JOURNAL OF ANIMAL SCIENCE 12(1): 227–234.

The report of the secretary which followed gave the membership for the fiscal year as 1235 domestic and Canada; 55 foreign; or a total of 1290 members. This represented a gain of 50 members over the previous fiscal year.

Subscriptions to the JOURNAL OF ANIMAL SCIENCE for the year totaled 1,000. Of this number, 451 were domestic and 549 were foreign. Approximately 300 libraries were reported to be subscribers to the JOURNAL.

Subscriptions for the year represented an increase of 195 over those in effect during 1952. During the past two years (1952–1953) there had been an increase of 361 subscriptions to the JOURNAL. Past reports show that it was not until the JOURNAL's fifth year (1946) that subscriptions totaled as many as 350. The total number on the mailing list for the JOURNAL in 1946 was reported to be 1,053. For 1953, the total number was 2,290.

During the year the office of the secretary had sent three letters to the entire membership and one or more letters to each subscriber in addition to the usual correspondence necessary in the conduct of business concerning the Society and the JOURNAL.

The treasurer's report showed that income to the Morrison Award Fund amounted to $1,651.95 for the year. Expenditures amounted to $1,049.53. The balance on hand in this fund on November 1, 1953 was $2,650.20.

The income to the General Fund of the Society for the fiscal year (November 1, 1952–October 31, 1953) amounted to $23,412.09. The expenditures during the year totaled $16,817.37, which left an operating gain of $6,594.72 for the year. The cash balance on hand in the General Fund at the close of the year was $12,515.41. In addition, the

Society has assets of $4,550.00 in U. S. Bonds, Series F, and $7,000.00 in U. S. Bonds, Series G.

The Auditing Committee, consisting of W. J. Loeffel, W. W. Green and Doyle Chambers, reported the treasurer's books in good order and the balances in agreement with the bank balances and the treasurer's report to the Society.

The editor of the JOURNAL OF ANIMAL SCIENCE, L. E. Casida, gave the following report:

"A total of 934 papers has been considered for publication in the JOURNAL OF ANIMAL SCIENCE from its beginning 12 years ago through November 15, 1953. Of these, 775 have been published.

"Publication during 1953 (Volume 12) included 104 papers, the president's address and other Society proceedings of the 1952 meeting (including memorials, awards, and committee and program chairmen for 1953), 156 abstracts of papers presented at the 1953 annual meeting of the Society, subject and author indexes of Volume 12, and the usual News and Notes Section in each of the four issues of the JOURNAL

"Manuscripts received during the period from November 16, 1952 to November 15, 1953, totaled 127. Of these 9 have been withdrawn or rejected, 66 have been published, 33 are in press to appear in the February, 1954 issue, 10 are being revised by the authors and 9 are being reviewed by the Editorial Board. All papers on which editorial work had been completed at the time were sent to press for each of the four issues.

"Note should be taken of the fact that a peak in number of manuscripts submitted was reached at 122 in 1950. There was a decline to 116 in 1951 and further to 100 in 1952. Manuscripts submitted in 1953, 127 in number, represent a new and higher peak in the activities of our society.

"The Editor wishes to announce that the terms of E. P. Reineke and R. H. Burns on the Editorial Board will expire on December 31, 1953. The Executive Committee has appointed W. D. Gallup as Assistant Editor and L. E. Harris, C. E. Terrill and A. V. Nalbandor as new members of the Editorial Board."

The records of the business manager of the JOURNAL OF ANIMAL SCIENCE listed the following back numbers of the JOURNAL available for sale:

Vol.	Year	Complete Volumes	Number of copies in single issues			
			No. 1	No. 2	No. 3	No. 4
1	1942	0	0	0	6	23
2	1943	0	35	23	0	4
3–6	1944–47	0	0	0	0	0
7	1948	0	0	0	9	0
8	1949	0	0	0	4	1
9	1950	0	0	0	31	66
10	1951	0	0	108	0	62
11	1952	0	0	0	100	163
12	1953	122	127	132	142	122

These back numbers may be purchased from the business manager at the following rates: Volumes 10–12, $1.75 per single copy for domestic and $2.00 for foreign; for preceding issues, $1.00 and $1.25, respectively. In addition, the following Proceedings of the American Society of Animal Production may be purchased at a cost of $1.00 each for domestic and $1.25 each for foreign.

1915–16	50	1931	63
1920	1	1932	22
1922	339	1934	27
1923	231	1935	32
1925–26	47	1936	1
1927	49	1938	4
1929	33	1939	4
1930	20	1940	54

The report of the Nominating Committee was given by P. S. Shearer and was as published in the November, 1953, issue of the JOURNAL. No further nominations were made. A. E. Darlow was declared elected as President and J. I. Miller was declared elected as Vice President. Ballots were distributed for voting on Secretary-Treasurer.

The following report of the Committee on Investigations was given by C. M. Kincaid:

"The Investigations Committee has continued its work toward the publication of a monograph on research techniques. Dr. Clair Terrill, who was chairman of this committee when this project was started has been in charge of handling the manuscripts. Of five sections to be in the monograph three have been completed and are ready for the printer. The other two sections have tentative deadlines of February 1, 1954. It is the objective of the Committee to have all sections in manuscript form and in the hands of the printer by the 1954 annual meeting."

The following report by the Committee on Information was given by H. H. Biggar:

"News releases covering papers presented at this 45th annual meeting of the Society are being released to the Chicago papers, Chicago City News Bureau, and the press wire services including the Associated Press, United Press and International News Service. Releases are also going out to the publications in the livestock and agricultural field—including market papers, farm papers, general livestock publications and publications devoted especially to cattle, hogs and sheep.

"This of course is the logical time to report on the use of news releases from the 1952 meeting of the Society. And in that connection we can only cite those which have come to our attention carrying one or more of these news stories. Stories resulting from releases sent out last year have appeared in the Western Livestock Journal, California; St. Louis Livestock Reporter, St. Louis stockyards; Oklahoma Live Stock News, Omaha Daily Journal Stockman, Chicago Drovers Journal, Kansas City Drovers Telegram, St. Joseph, Missouri Livestock Journal,

the Kansas Stockman, Breeder Stockman of Virginia, California Live Stock News, Livestock Weekly of Memphis, Tenn.; The Cattleman, Fort Worth, Texas; Berkshire News at Springfield, Ill.; Poland China World, Galesburg, Ill.; Shorthorn World of Aurora, Ill., Polled Hereford World of Kansas City, Mo.; National Provisioner, Chicago; Meat Magazine, Chicago, and the Butchers' Advocate, New York City.

"During the year we have noted advance stories concerning the selection of Professor Shearer as the honor guest of the Society but we have no record as to the extent of the use of this story sent out we assume by the committee in charge of this event.

"Through a clipping bureau which was asked to clip any items relative to the Society, clippings have been received from papers in five different states—Illinois, Kansas, California, New York and Washington. In the Illinois list were three Chicago dailes—The Chicago Daily News which carried Dr. Weber's picture as the honor guest of last year—the Chicago Tribune and the Chicago Herald American. Other Illinois papers using stories were the Champaign News Gazette—Danville Commercial News and the Jackson Courier. California papers carrying stories included the Sacramento Bee, Visalia Times, Berkeley Gazette and the Los Angeles Examiner. Kansas papers carrying stories were the Manhattan Mercury Chronicle, Manhattan Tribune, and the Topeka Capital. News stories were also carried in the New York Herald Tribune and the Seattle Washington Times. These daily papers I have mentioned have a total circulation of over 3¼ million—that is, they go into 3 million, 250 thousand homes."

A. E. Cullison, Chairman of Necrology, presented the names of members who passed away during the year. Memorials are published in this issue of the JOURNAL. Members stood in silent respect.

A report on the activities of the Agricultural Research Institute for 1953 was given by J. O. Grandstaff as follows:

"The second annual meeting of the Agricultural Research Institute was held jointly with the Agricultural Board on November 23 and 24 at the National Academy of Sciences. An excellent program was presented on the following main topics: (1) Relationship of the Agricultural Research Institute to the National Academy of Sciences and the National Research Council, (2) The Activities of the Agricultural Board, and (3) Research and the Attainments of Agriculture.

"The following officers were elected for next year: P. D. V. Manning, International Minerals and Chemical Corp., President; B. S. Clark, American Can Co., Vice President; R. M. Bethke, Ralston Purina Co., Secretary.

"A Membership Committee serves to acquaint the heads of industry concerned with agriculture and agricultural products with the aims of the Institute and invite them to become Class A members. The Committee reported that contacts were made with approximately 200 corporations during the year, resulting in a small increase in membership. This activity is to be expanded and intensified during the coming year. Membership of government and academic organizations (Class B membership) is through nomination by the National Research Council.

"The Committee on Projects and Proposals reported that it had solicited suggestions from all Class A and Class B members regarding agricultural problems or projects and on ways and means of promoting more efficient cooperation between

industry and government in agricultural research. Approximately 200 suggestions were received, which provided a basis for final recommendations.

"The Committee recommended that the Agricultural Board consider appointment of the following new committees: (1) Water Conservation and Utilization; (2) Plant Diseases and Pests; (3) Farm Machinery and Mechanization; (4) The Broad Problem of Fats and Oils in the Nutrition and Economy of the United States from the Agricultural Point of View; (5) Cooperation in Research Between Research Workers in Industry and Federal and State Agencies; and (6) Metabolic Disturbances with Special Emphasis on Bloat under the General Committee on Animal Health.

"Funds available in the budget of the Agricultural Research Institute for the current year, all of which was derived from Class A membership fees were used to finance two meetings of the Agricultural Board, and meetings by the Committee on Animal Health and the Committee on Brucellosis."

The secretary presented the following report on the European Association of Animal Production which had been prepared by R. W. Phillips:

"The European Association of Animal Production now includes national animal husbandry organizations from eighteen countries, as listed in the report in 1952 (J.A.S. Vol. 11, No. 4). The Association is continuing its practice of holding Study Meetings, the third of which was held in Siena, Italy, from September 6–11, 1953. This meeting dealt with technical problems of meat production in Europe, and included lectures and practical demonstrations of the different methods of cutting carcasses as practiced in various European countries. Carcasses of cattle, sheep and swine were available from the Netherlands, France, Denmark and Italy.

"A fourth Study Meeting is planned for September 1954, in Switzerland, to deal with the influence of environmental factors on animal production. In addition to the third Study Meeting, the Association cooperated with the Food and Agriculture Organization of the United Nations in a meeting on problems of animal feeding in Europe, which was held in Paris on March 23–28, 1953. Also, the Association is engaged in the compilation of a glossary of terms used in animal production, which it is hoped will be published in English, French, and German.

"In the 1952 report reference is made to six permanent Study Commissions that had been established by the Association. The Commission on Research has been giving attention to the possibilities of co-ordination of research work in the field of animal production. The Commission on Animal Nutrition has given attention (a) to the establishment of a standard method of measuring the nutritive values of feeds; (b) to the compilation of a manual on techniques of experimental work on digestibility of feeds; and (c) possibilities of developing a standard method for the calculation of production requirements, possible further work on the determination of the net energy value of home-produced feeding stuffs, re-examination of the methods of analyzing feeding stuffs, attention to the use of antibiotics in animal feeding, and the possibilities of basic research on fermentation processes in silage making. The Commission on Horse Breeding has not yet anything specific to report. The Commission on Cattle Breeding has finalized a draft of a breeders' guide containing the essential principles of the organization of cattle breeding in Europe, intended as a guide to practical

breeders, and as a contribution to extension work. A study has also been undertaken on the methods of keeping and operating herd books in Europe. Also, a bibliography on the more important recent publications on cattle breeding is being compiled, with the hope that it may be published as an annex to the breeders' guide referred to earlier. The Commission on Sheep and Goat Breeding has prepared a draft manuscript on standard methods of milk recording for sheep and goats, and two papers have been prepared as a basis for discussion on performance tests for the determination of meat-producing capacity of sheep. The Commission on Pig Production is carrying out a survey of pig production and pig recording methods in various European countries, and is also undertaking a study of trends in the prices for pigs in European markets."

F. F. McKenzie announced a joint meeting of the Western Section of the American Society of Animal Production and the Western Division of the American Dairy Science Association to be held at Oregon State College, July 11–14, 1954.

The report of the Resolutions Committee, consisting of K. L. Turk, Chairman, George Litton and N. W. Hilston was read and approved as follows:

"The Committee on Resolutions of the 45th annual meeting of the American Society of Animal Production wishes to express its sincere appreciation and thanks as follows: (1) To the officers and committee members for their splendid work in the preparation of another fine program, excellent conduct of the annual meeting and for keeping the business of the Association in excellent order. We especially wish to thank Professor J. I. Miller for his conscientious work as secretary-treasurer during the past three years. (2) To Professor and Mrs. F. B. Morrison for making available the Morrison Award and its continuing stimulation for outstanding research in livestock production. (3) To the management of the Sherman Hotel again this year for their splendid cooperation in providing excellent facilities for the conduct of our annual meeting. (4) To the American Feed Manufacturers Association for continuing their fine award for outstanding research in livestock nutrition for another 3-year period. (5) To Col. E. N. Wentworth our special thanks for his special effort to attend and give a fine talk in the opening session, in spite of his illness and extend to him our best wishes for a speedy return to good health.

"Because of the large number of papers submitted and the difficulties involved for the program committee in making the best selection for the greatest contribution to the livestock industry and to the individual members of the Society, it is requested that the Executive Committee of the American Society of Animal Production give consideration to procedures that might alleviate this situation. It is especially suggested that consideration be given to a requirement that a complete manuscript be submitted along with the abstract which will serve as a better basis for accepting papers than will an abstract alone."

President Baker called for a report of the tellers. This report given by W. G. Kammlade, announced the election of W. M. Beeson as secretary-treasurer.

The meeting adjourned at 3:20 p.m.

MEMORIALS

ORVILLE G. HANKINS

Orville G. Hankins, nationally known meat research specialist of the Bureau of Animal Industry, U. S. Department of Agriculture, died Friday, November 13, 1953, of a cerebral hemorrhage suffered the day before.

A native of Decatur, Illinois, Mr. Hankins was a graduate in Animal Husbandry of the University of Illinois. Following graduation he taught agriculture at Louisiana Polytechnic Institute, Ruston, Louisiana. He then served as Swine Extension Specialist for the University of Kentucky at Lexington, Kentucky, for several years, joining the Animal Husbandry Division of the Bureau of Animal Industry in 1920.

A veteran of more than 33 years service in the Animal Husbandry Division of the Bureau of Animal Industry, Mr. Hankins was at the time of his death, Head of the Meats Division of Animal and Poultry Husbandry Research of the Agricultural Research Service, with his headquarters at the Agricultural Research Center, Beltsville, Maryland.

He was a nationally known research authority on factors contributing to the quality and palatability of meat and worked tirelessly to develop methods for improving the meat supply of the nation.

He headed the meats research activities of the Animal Husbandry Division of the Bureau for 25 years prior to his death, during which time a wealth of information of direct practical application to the production, storage, and preservation, of quality meat has been developed under his leadership. He provided methodology for meat evaluation for genetic, nutritional and marketing studies, including the use of yield of preferred cuts as a measure of carcass quality. He was the author or co-author of a large number of bulletins, monographs, Yearbook articles, and scientific papers on meat subjects published by the Department of Agriculture and by both popular and scientific journals throughout the country. He was a contributing editor of the scientific journal, Food Technology.

He was a member of Ruston, Louisiana, Lodge of Masons, an active member of the Sherwood Presbyterian Church of Woodridge, of the American Society of Animal Production, the Institute of Food Technologists, the American Association for the Advancement of Science, and the Washington Academy of Science.

EDWIN BRET HART

Edwin Bret Hart, was born December 25, 1874 on a farm near Sandusky, Ohio, and was the youngest of a family of 12. His undergraduate work was done at the University of Michigan, where he received the B. S. degree in 1897. He early developed an interest in chemistry, especially analytical chemistry, and as an undergraduate was a special assistant to a distinguished professor of analytical chemistry, Dr. E. D. Campbell.

His first position was with the New York State Experiment Station at Geneva. At the beginning of the century he went to Germany to study under the famous biochemist, Albrecht Kossel. After two years in Germany he returned to Geneva, and in 1906 was invited to come to the University of Wisconsin as head of

the Department of Agricultural Chemistry and chemist in the Experiment Station.

Professor Hart has been a fruitful contributor to the field of research especially on the subjects of minerals and vitamins in nutrition. He and his associates established the role of inorganic phosphorus in the nutrition of animals. He was instrumental in the discovery that iodine is important in preventing goiter in animals, that copper and iron play important roles in hemoglobin building, and was closely associated with work on 12 or more vitamins. He is author or coauthor of nearly 400 scientific papers.

In addition to his many contributions to research, Prof. Hart was also an outstanding teacher and an effective administrator. As a lecturer he was pleasing, clear, and stimulating. He was a skillful and searching quiz master.

As an administrator he worked hard to keep a strong staff intact and enjoyed much success in this regard during the 38 years he served as the Head of his Department.

Professor Hart's pleasing voice and affable manner made him an effective public speaker both to scientific and lay audiences. He had great personal charm and a keen sense of humor which made him a delightful companion. He received many professional awards and honors among which were the Borden award from the American Dairy Association in 1941, election to the National Academy of Sciences in 1944, and an honorary Doctor of Science degree from the University of Wisconsin in 1949.

Professor Hart married Annie Virginia DeMille in 1903. His life was exceptionally rich in outstanding achievements and great leadership and in kindly inspiration to those who had the good fortune of knowing him. Professor Hart died suddenly at his home in Madison, Wisconsin on March 12, 1953.

MARSHALL C. HERVEY

Marshall C. Hervey was born May 30, 1913, on a farm in Ashtabula County, Ohio. His professional training was obtained at Ohio State University where he received a Bachelor of Science degree in 1935, a Master of Science degree in 1936, and a Doctor of Philosophy degree in 1938. He was a brilliant student and maintained practically a straight "A" average through his undergraduate and graduate work.

From 1937 to 1942, Dr. Hervey was Assistant and later Associate Professor of Animal Husbandry at the University of Tennessee. Soon after Pearl Harbor he joined the U. S. Navy and reached the rank of Lieutenant in 1945. In 1946 he returned to his former position at the University of Tennessee where he was advanced to the rank of Professor.

Dr. Hervey joined the staff of the Dairy Department at the University of Minnesota in 1949 with the rank of Associate Professor. His teaching has been in the field of dairy cattle breeding and selection. His research work in the field of genetics involving the use of identical twins and triplets has attracted wide attention. Dr. Hervey was popular not only as a teacher on the campus but also as a speaker at meetings of farmers and livestock breeders.

Among the college honor organizations of which Dr. Hervey was a member are Alpha Zeta, Gamma Sigma Delta, Phi Eta Sigma, Phi Lambda Epsilon and Phi Kappa Phi. He was also a member of the American Dairy Science Association, American Genetics Association, and American Society of Animal Production.

In 1949–50 he was a member of the Technical Committee of the Regional Dairy Cattle Breeding Committee, and last year served as Chairman of the Executive Committee, North Central Regional Cooperative Research Project on Improvement of Dairy Cattle through Breeding.

A fruitful career of teaching and research in dairy cattle breeding was brought to an untimely end by the passing of Marshall C. Hervey on January 25, 1953, at the University of Minnesota hospitals.

RAYMOND ROSCOE SNAPP

Raymond Roscoe Snapp was born at Findley, Illinois, December 13, 1889. He attended Eastern Illinois Teachers' College 1908–10, the University of Chicago, 1910–11 and the University of Illinois, 1911–13, receiving his A.B., B.S., and Ph.D. from the latter.

He taught at John Swaney High School, 1913–14 and at the University of West Virginia, 1914–15. He came to the University of Illinois, September 1, 1915, as Instructor in Animal Husbandry and in 1939 he was named Professor of Animal Husbandry and Head of the Beef Cattle Division.

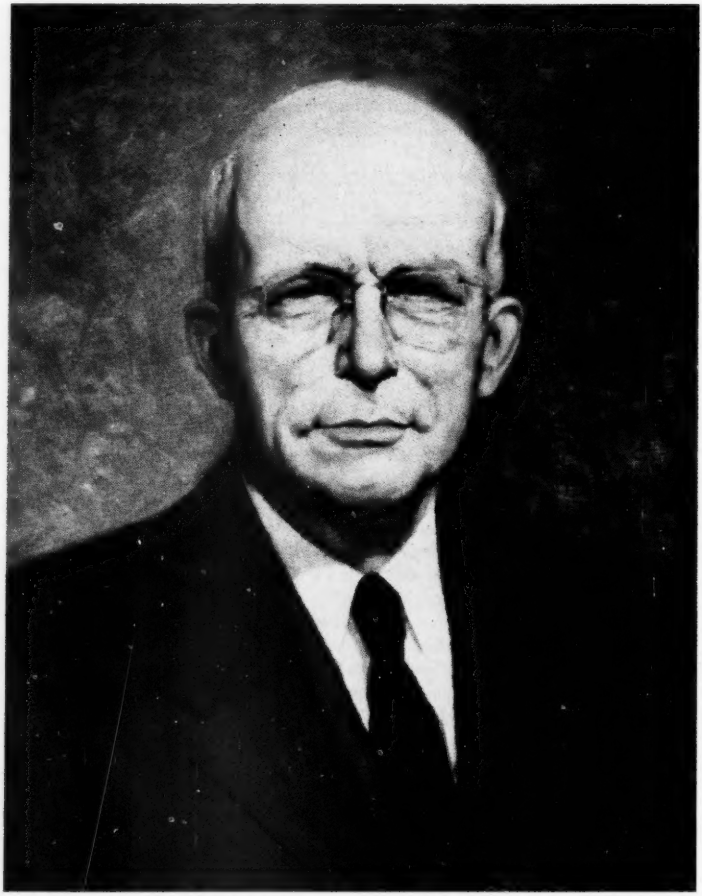
He saw over-seas service in both World Wars, serving as a Captain of Field Artillery and Battery Commander from 1917 to 1919 and as a Colonel from 1942 to 1945. He was in the Reserve Corps between wars and after World War II.

His contributions to the science of beef production were widely recognized and appreciated. He was the author of many experiment station publications and a widely used text book "Beef Cattle," now in its fourth edition.

Prof. Snapp was a loyal member of the First Methodist Church of Urbana, the American Society of Animal Production and the honorary societies, Sigma Xi, Phi Kappa Phi, Alpha Zeta and Gamma Sigma Delta.

He was a sympathetic teacher, an exacting researcher, a conscientious soldier and an ideal Christian gentleman. He practiced what he believed. He was generous with both his time and goods in helping his church and the underprivileged. With it all he was modest, unassuming, tolerant and broad minded.

Dr. Snapp passed away at Urbana, Illinois, June 25. 1953.



PHINEAS S. SHEARER

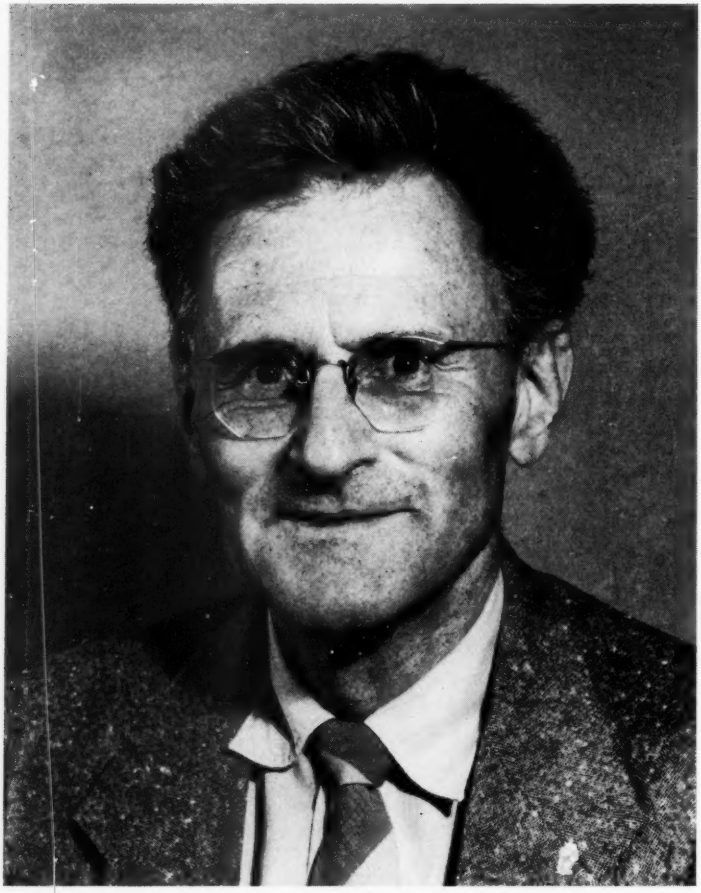
Reproduction of a portrait presented to Saddle and Sirloin Club in Chicago by the American Society of Animal Production on November 29, 1953. Phineas S. Shearer was the Honor Guest of the Society during its Annual Meeting which was being held at that time.

PHINEAS S. SHEARER

Honor Guest—1953

Phineas Stephens Shearer, the Honor Guest for 1953, was reared on a livestock farm near Melbourne, Iowa, and has been identified with livestock teaching and research all his life. Immediately after graduation from Iowa State College, he spent a year as an instructor in animal husbandry at the University of Nebraska. He then returned to Iowa State College, where he served at various times as coach of the livestock judging team, in charge of the animal breeding teaching and research, and as responsible for the work in sheep husbandry. For the last 20 years his primary subject matter specialty has been the work with beef cattle. He is well known nationally as a judge of beef cattle. He has been head of the animal husbandry department since 1935.

His research and publications have mostly concerned problems of sheep and beef cattle husbandry and breeding problems such as cross-breeding in swine and how to utilize the Record of Performance procedures for swine improvement. He served the American Society of Animal Production as vice-president in 1949 and as president in 1950. Through his sound counsel and broad outlook, he has had a strong influence on many teaching and research programs, both in his own and other states.



MAX KLEIBER

Max Kleiber received the eighth Morrison Award which was presented to him during the 45th Annual Meeting of the American Society of Animal Production in Chicago on November 28, 1953.

THE MORRISON AWARD

1953

The recipient of the Morrison Award for 1953 has a philosophical attitude toward research all too seldom exemplified in research workers in the field of animal production today. He accepts the conclusions of no one without thorough study of the evidence. He is truly an independent thinker contributing to our thinking as well as to our body of knowledge concerning energy metabolism and evaluation of feeds.

Particularly outstanding are the recipient's contributions regarding the many factors influencing metabolic rate: body size, environmental temperature, nutritive deficiencies, age, anesthesia, organization of tissue, lactation, pregnancy, starvation and exogenous hormones. His more recent studies using radio-active isotopes are laying a sound foundation for intermediate metabolism studies in the large domestic animals. His studies on the relationship of environment, especially nutritive deficiencies, to food utilization have yielded information of particular importance in the field of animal production.

Dr. Max Kleiber, born in Zurich, Switzerland on January 4, 1893, took both his undergraduate and graduate work at the Swiss Federal Institute of Technology receiving the D.Sc. degree in 1924. He continued on at that institution holding an assistant professorship until 1929 when he received a professorship in Animal Husbandry at the University of California, a post he has occupied since that time.

The pre-eminent position which he holds in the field of metabolism is indicated by: nine invitations to write review papers, the 1952 Borden Award in nutrition, the many visiting scientists he has attracted, his appointments to committees on the National Research Council, Office of Naval Research and the Atomic Energy Commission, and finally by the generous research grants he has received.

Dr. Kleiber's research will play an important role in establishing standards for energy requirements of domestic animals. His teaching at both the undergraduate and the graduate levels is inspiring and sound.

DAMON CATRON

Damon Catron was awarded the sixth American Feed Maunfacturer's Association award, which was presented to him during the 45th Annual Meeting of the American Society of Animal Production in Chicago on November 28, 1953.

AMERICAN FEED MANUFACTURERS ASSOCIATION AWARD

1953

Damon Von Catron was born in Russiaville, Indiana, September 12, 1915. He was graduated from Purdue University with a B.S. degree in 1938. He received his M.S. degree with a major in Animal Husbandry from the University of Illinois in 1945 and his Ph.D. in Animal Nutrition from Iowa State College in 1948.

He has held the following positions:

Instructor in Vocational Agriculture, New Castle, Indiana	1938–40
Associate in 4-H club work, Purdue University	1940–41
Livestock and Poultry Specialist, Purina Mills, St. Louis	1942
Associate in Animal Husbandry, University of Illinois	1943–44
Nutrition Specialist, Honegger's Co., Forrest, Ill.	1944–45
Assistant Professor of Animal Husbandry, Iowa State College	1945–48
Associate Professor of Animal Husbandry, Iowa State College	1948–53
Professor of Animal Husbandry, Iowa State College	1953–

Dr. Catron's contributions to the field of Animal Science have been especially valuable in the area of swine nutrition. His untiring energy and enthusiasm and his capacity to get things done have enabled him to accomplish much in the years covered by his endeavors in this field. Practically all aspects of cornbelt swine production have been investigated in the experimental program for which he has been responsible. Cooperation with workers in the related fields of Biochemistry, Bacteriology, Veterinary Medicine, Agricultural Engineering, Economics and Statistics has broadened the scope and effectiveness of his work and of his contributions.

In addition to his research work, he has been an inspiring teacher of both undergraduate and graduate students. He has served for a number of years as a member of the Feed Survey Committee of the American Feed Manufacturer's Association and his services have been in great demand as a speaker at Nutrition Conferences and Swine Producer's meetings all over the United States.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN, AND SPECIAL ASSIGNMENTS FOR 1954

Standing Committees

Committee on Investigation.....C. M. Kincaid
Committee on Instruction.....F. N. Andrews
Committee on Extension.....E. S. Matteson
Committee on Membership.....J. I. Miller

Special Committees

Committee on Information.....R. C. Pollock
Committee on Necrology.....W. P. Garrigus
Committee on Nominations.....G. Bohstedt
Committee on Morrison Award.....J. I. Miller
Committee on American Feed Manufacturer's Award.....M. A. Alexander
Committee on Registration and Facilities.....W. M. Beeson

Program Committees

Breeding and Genetics.....C. R. Henderson
Extension.....E. S. Matteson
Meats.....C. H. Adams
Nutrition.....W. E. Dinusson
Pastures and Forages.....W. C. Weir
Physiology.....N. L. Van Demark

Special Representatives

Inter-Society Cooperation.....J. E. Foster
American Association for Advancement of Science Council.....L. N. Hazel
Division of Biology and Agriculture, National Research Council....J. O. Grandstaff
European Association of Animal Production.....R. W. Phillips
Ralston Purina Award Committee.....R. H. Nelson

NEWS AND NOTES

Applications for the Ralston-Purina research fellowship should be on file by March 1. Application blanks may be obtained from the Ralston-Purina Research Awards Committee in care of Mr. George H. Kyd, Ralston-Purina Co., St. Louis, Missouri. The fellowships are for $1560 annually and awards will be made in the fields of nutrition and physiology research as applied to dairy, poultry, and animal husbandry, and in research in transmissible diseases of livestock and poultry. Individuals qualified for graduate study in any Land-Grant Agriculture College and approved Veterinary Colleges are eligible.

The Western Section of the American Society of Animal Production will hold its 1954 convention on the campus of Oregon State College, Corvallis, from Sunday evening, July 11 through Wednesday noon, July 14, 1954. This meeting will be joint with the Western Division of the American Dairy Science Association.

Dairy Cattle Feeding and Management (4th Edition) by H. O. Henderson and P. M. Reaves was published by John Wiley and Sons, Inc., New York in January 1954. Recent material has been incorporated into various chapters and several new chapters are included dealing with special aspects of feeding, breeding and marketing.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts". *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest concerning the members, and other items of interest to the membership. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. L. E. Casida, Department of Genetics, University of Wisconsin, Madison, Wisconsin, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. W. M. Beeson, Department of Animal Husbandry, Purdue University, Lafayette, Ind., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.